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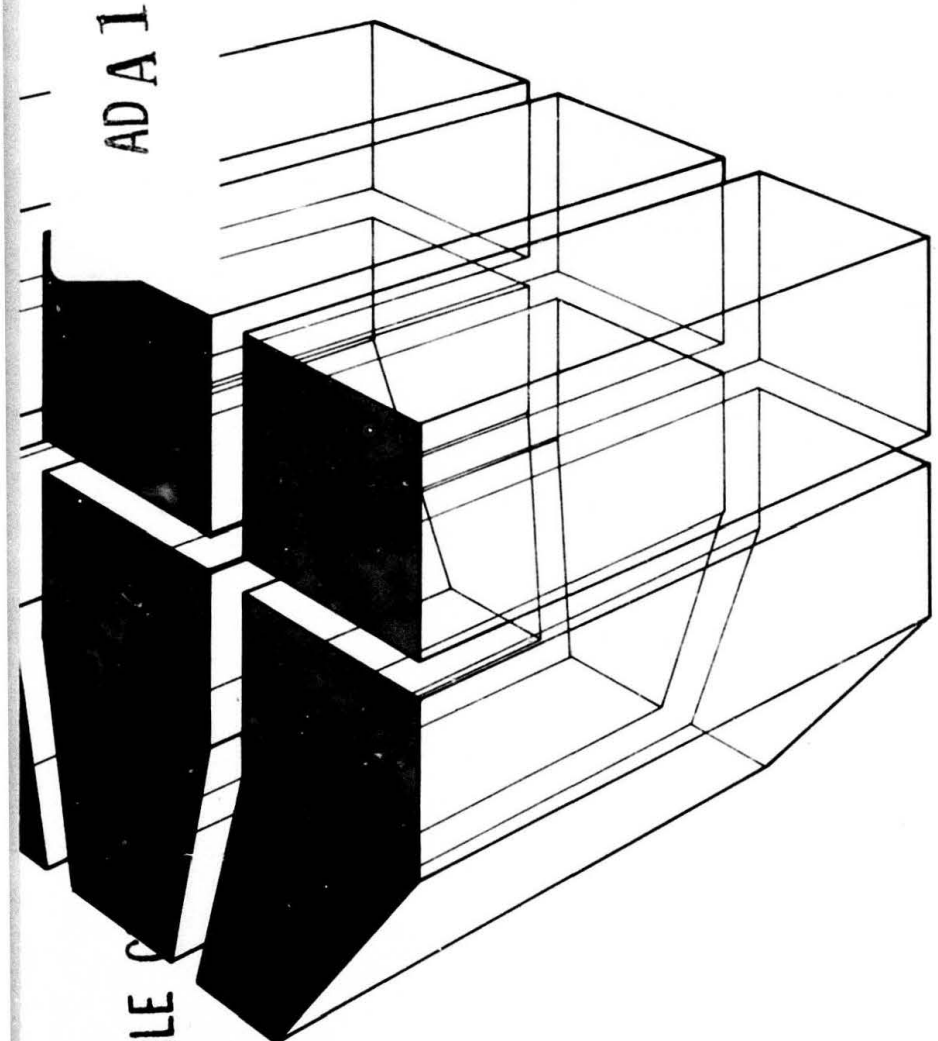
Training Area Maintenance

AN OVERVIEW OF POTENTIAL METHODS FOR MAINTAINING TRAINING AREA ENVIRONMENTS IN ARID AND SEMI-ARID CLIMATES



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The available land base on which the Army can effectively train troops remains relatively constant, while the mechanization and mobility of units training in the field are increasing. The resulting intensity of training is placing enormous pressure on the training area environments; this could reduce the effectiveness of training because of a reduction in the realistic training atmosphere of the areas. This increased stress on the land has

BLOCK 20 (CONT'D)

required the lands manager to seek improved methods of maintaining training areas.

This report presents a general overview of several techniques and types of equipment that can be used for land maintenance in the arid and semi-arid regions of the United States. This material is intended to give the land manager a generic view of the various methods and to provide preliminary information useful for developing techniques for maintaining training areas. The advantages and disadvantages of each technique or piece of equipment are discussed. The information in this report will allow users to develop a land maintenance field-testing program at the local level. A checklist is provided to help the manager acquire the information needed to begin a stronger maintenance program.

FOREWORD

This investigation was performed for the Assistant Chief of Engineers by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL). The work was done under Project 4A762720A896, "Environmental Quality Technology"; Technical Area B, "Source Reduction Control and Treatment"; and Work Unit 036, "Training Area Maintenance." The OCE Technical Monitor was Mr. Donald Bandel, DAEN-ZCF-B.

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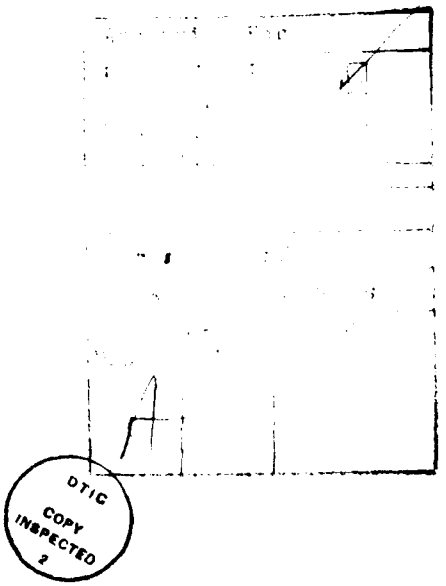

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AN OVERVIEW OF POTENTIAL METHODS FOR MAINTAINING TRAINING AREA ENVIRONMENTS IN ARID AND SEMI-ARID CLIMATES

1 INTRODUCTION

Background

The Department of the Army manages nearly 12 million acres (4,858,300 ha) of land used for training. Although this is a great deal of land, the amount of acreage needed to train military units has increased. In a combat situation, the average battalion is expected to move within an area as large as 80,000 acres (32,385 ha). Provision of realistic training requires an area this large; however, increased training activities have placed increasing stress on the land base. Training activities can drastically alter an installation's soil structure and vegetation and thus adversely affect the overall environment. Ecological damage occurs during clearing operations and when training vehicles run over and crush vegetation, displace soil, and sideswipe trees. Such damage can be especially severe in dry climates which are particularly susceptible to erosion and where it is hard to re-establish vegetation. The National Environmental Policy Act (NEPA) and AR 200-2[1] require the Army to minimize any significant short- or long-term impact to the environment.

To meet these objectives, increasing emphasis will be placed on active maintenance of military lands. A group of military land managers, training officers, and environmental officers determined that the first step in a research program should be to compile land management techniques that can be used on military land.[2]

Objective

The objectives of this study were (1) to review information on techniques for maintaining and rehabilitating arid and semi-arid environments, (2) to synthesize this information in order to make it more suitable for the Army-unique use of lands, and (3) to present this information so that the Army lands manager can use it to develop a viable local land maintenance and rehabilitation program.

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[1] National Environmental Policy Act of 1969, P.L. 91-190, 83 Stat. 851; Environmental Quality; Environmental Effects of Army Actions, AR 200-2 (Department of the Army, 20 October 1980).

[2] Training Range Environmental Research User Group Meeting, held at Fort Knox, KY, 23-24 November 1981.

Approach

A literature survey was conducted to identify techniques used to reclaim drastically disturbed land, including trail areas, in the arid southwest. Informal discussions were held with land managers and environmental officers at the major Army installations in the Southwest to identify land reclamation techniques that have been tried and their rates of success. Information obtained was analyzed and synthesized to provide state-of-technology guidance applicable to Army-unique problems. Based on an analysis of the information gained from the literature and the installations, a land rehabilitation technique checklist was developed, a synthesis of potential useful training area and trail rehabilitation techniques was presented, and existing installation programs were discussed. Additional information concerning seed acquisition, the Plant Information Network, and types of equipment was presented.

Scope

The techniques discussed in this report are primarily those used in the arid and semi-arid areas of the continental United States. Although many of these techniques can be applied in other climatic areas, care must be taken in such applications.

The information provided here is preliminary and reflects the analysis of initial research in this area.

Mode of Technology Transfer

It is recommended that the information in this report be disseminated through a training circular in the TC 25 series, "General Management."

2 LAND REHABILITATION PLANNING IN THE SOUTHWEST

This report discusses techniques commonly used in the arid and semi-arid portions of the United States to revegetate damaged areas. The information is designed to meet the needs of installations found in the prairie division of the humid temperate domain and in the steppe and desert division of the dry domain listed in Bailey's Ecoregions.[3] This region includes the area west of the Kansas prairies to the leeward side of the Rocky Mountains. Lack of available moisture for plant growth was the overall criterion used to select the areas included in this category. Average annual precipitation varies from 2 to 40 in. (50.8 to 1016 mm) per year. Although 40 in. (1016 mm) of rainfall are enough for many plants, it is the availability of this moisture which is the greatest concern. In areas where there is enough rainfall for plant growth, the timing, frequency, or intensity of storms might make the moisture unavailable. For example, the amount of rainfall from a large storm may rapidly exceed the soil's infiltration rate; as a result, most of the moisture would run off and plants could not use it.

The native vegetation changes with varying amounts of precipitation. In the eastern section, the dominant vegetation is tall grasses; the common vegetation species are big and little bluestem. Moving westward into the steppe or short grass prairie, typical vegetation includes many species of grasses (e.g., buffalo grass) which are found in scattered bunches. Xerophytic shrubs with a poorly developed herbaceous layer, such as sagebrush are found in the semidesert or steppe region. The desert areas contain widely spaced xerophytic plants with negligible ground cover. Some areas may be in sterile salt flats or shifting sand dunes with no vegetation.

Soils are highly variable throughout this area. Organic matter decreases as one moves westward. In the eastern area, the soils are mostly mollisols. Further west, calcification occurs, with accompanying salinization on poorly drained sites. Soils become basic due to large amounts of precipitated calcium carbonate. Mollisols are found in the short grass prairie or steppe regions. Aridisols are found in the semidesert.

Table 1 lists major military installations where training occurs in the southwest and shows where they fit within this system. Bailey[4] provides more detailed descriptions. Land rehabilitation programs at several of these installations are discussed in Chapter 5.

The techniques discussed in this report were chosen from Government and technical literature describing stripmine and rangeland reclamation in the arid and semi-arid southwest. However, there are major differences between the effects of stripmining, overutilizing ranges, and using areas for military training. Stripmined reclamation areas include sites which have been more disturbed than military training areas. In many cases, particularly older mines, soil horizons have been mixed and/or inverted. Where topsoiling is not done, the "soil" often varies from highly phytotoxic to sterile. Even where

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[3] Robert G. Bailey, Description of the Ecoregions of the United States, Miscellaneous Publication No. 1391 (United States Department of Agriculture [USDA], Forest Service, October 1980), pp 44-58.

[4] Bailey, pp 44-60.

Table 1

Selected Major Military Installations With Training Areas
in the Southwest Classified by Bailey's Ecoregions

DRY DOMAIN

Desert Division

White Sands Missile Range
Fort Irwin
Yuma Proving Ground
Fort Bliss

Steppe Division

Fort Ord
Fort Carson
Dugway Proving Ground
Fort Huachuca
Yakima Firing Center
Fort Hunter Liggett

HUMID TEMPERATE DOMAIN

Prairie Division

Fort Sam Houston
Fort Riley
Fort Sill
Fort Hood

topsoil has been "stockpiled," there may be loss of soil fertility due to leaching of nutrients and loss of soil microorganisms.

Rangeland rehabilitation often involves land that has been overused. Overuse decreases range quality, allows invasion by noxious and undesirable plants, and sometimes causes compaction and erosion.

The degree of destruction in training areas lies somewhere between that of stripmining and rangeland overuse. Destruction of vegetation by mechanical injury and compaction has left many areas denuded and eroding. In some areas, invasion of noxious vegetation has become a problem. A major difference between reclaiming rangeland or stripmined areas and maintaining training areas is the land's ultimate use. Reclaimed military training areas tend to

encompass the multiple-use concept. The first objective of any military land manager is to provide the units assigned to the post with the most realistic training areas possible within the constraints placed by both the land's capability and the facility's budget. The manager must consider both the units training now and those which will use the installation in the future. Doing this requires close coordination with the post's training officer. Due to the high intensity of use, a site cannot lie fallow for long periods of time. After the military objective is met, the land manager must consider all other potential uses of the land, including agriculture/forestry, wildlife, recreation, and environmental conservation. Although the stripmine reclamation specialist must consider many of these same objectives, the lack of national defense considerations makes the task much easier.

At this time, there is no universally accepted methodology for determining when a military training area needs rehabilitation; however, current research is trying to provide one. The best method now relies exclusively on the military land manager's professional judgment. In the southwest, this often reflects judgment based on the quality of range; that is, the ability of the land to carry cattle, sheep, or horses. This may or may not reflect the land's ability to carry military units.

Once it is decided that an area needs rehabilitation, soil tests will generally be run. Such tests are needed to determine the condition of the soil's structure, type, salinity, pH, and nutrient availability. This information, along with climate and current vegetation, will provide the basis for conducting the rehabilitation. Chapter 4 discusses several techniques which can be used in many combinations for different effects. Not all the techniques are practical or useful at all times and in every situation. The user must choose one or a combination of techniques that is most suitable for the situation.

The first step in site rehabilitation is preliminary planning. This involves gathering the basic information needed to conduct the rehabilitation effort. At this point, all major decisions must be made regarding the entire operation; also, the training officer should become involved now. The type of training will have a large impact on such decisions as type of grading, choice of vegetation, choice of an irrigation scheme, etc. It is the land manager's job to balance what the training officers want with the reality of what the land can support, based on the area's budget and biology. Sources of funding, equipment, and manpower must be identified early, preferably during this phase. Some work can be performed by lessees of the land in lieu of rent. However, there must be some restrictions, since the work must benefit both the lessees and the Army and must be done on the leased tract.

Land rehabilitation can also be done by contract. This has the advantage of not requiring the Army to obtain and operate specialized equipment. There are firms which specialize in reclaiming stripmined lands; they may also be useful for a rehabilitation program, either as advisors or to perform the work. Doing the work in-house provides greater flexibility; however, at many installations, it has the disadvantage that land management crews are already working at full capacity. Thus, the cost of doing the work through outleases, in-house, or contract can be determined only at the local level. Several sources can be helpful at this stage (see Appendices A and C).

3 MAINTENANCE TECHNIQUES FOR AREA REHABILITATION

This chapter provides an overview of techniques that may potentially be used to maintain heavily used training areas in the southwest. Much of this information is based on two Forest Service reports.[5]

The techniques described have been developed for reclaiming stripmines and other drastically disturbed lands in the region.

Each technique is discussed generally; there has been no attempt to give a detailed description of equipment selection, cost, or availability, since these questions will require more research at the local level. Also, this discussion will not cover fire, fire control, herbicide/pesticide application, control of domestic stock or wildlife, or monitoring an area for significant deterioration.

Sequencing of the rehabilitation will vary somewhat, depending on the site conditions and the ultimate goal of the project. The operations can be broken into the following phases: (1) presite planning, (2) site preparation, which involves removal of unwanted vegetation, primary tillage and/or grading, and secondary tillage, (3) fertilization/pH control, (4) species selection, (5) planting, (6) mulching, and (7) irrigation and removal of irrigation equipment, and (8) monitoring. The first seven phases are discussed in the remaining sections of this chapter; however, removal of irrigation and monitoring are not treated in this report.

Depending on the site, techniques, and equipment used, some steps may be deleted and others may be combined. For example, fertilization/pH control and seeding may be combined in a single operation or fertilization may be combined with irrigation.

Presite Planning

Baseline information must first be obtained before starting a maintenance/rehabilitation program. This information relates not only to the natural environment but also to the rehabilitation effort. Table 2 provides a detailed list of basic data that should be gathered or known about the site before starting rehabilitation.[6] Although all areas are important, some are less important than others. The relative importance of a project is best determined at the local level. The asterisks in Table 2 identify the parameters which potentially have the greatest impact on revegetative efforts. The

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[5] User Guide to Vegetation, Mining, and Reclamation in the West, General Technical Report INT-64 (Intermountain Forest and Range Experiment Station, USDA, Forest Service, 1979); John E. Larson, Revegetation Equipment Catalog, prepared by Vegetative Rehabilitation and Equipment Workshop (VREW) (USDA, Forest Service, Equipment Development Center, 1980).

[6] W. D. Severinghaus, R. G. Goettel, and L. L. Radke, Establishing Priorities for Acquiring Natural Resources Data Parameters, Technical Report N-121/ADA109720 (U.S. Army Construction Engineering Research Laboratory [CERL], November 1981), pp 37-40.

Table 2

Basic Data Needed Before Beginning Land Rehabilitation

Data Parameters Index

*A. Soil Parameters
- *1. Fertility
- *2. Stability
- *3. Depth to Parental Material/Bedrock
- *4. Series and Type Classification
- *5. Soil Horizon/Profile
- *6. Texture
- *7. Structure
- *8. Consistence
- *9. Color
- *10. Reaction
- *11. Chemical Composition
- *12. Organic Matter or Content
- *13. Exchangeable -- Sodium Fraction
- *14. Permeability
- *15. Available Water Capacity
- *16. Depth to Seasonally High Water Table
- *17. Soil Capability to Class, Subclass Unit
- *18. Soil Productivity
- *19. Susceptibility to Sheet Rill Erosion
- *20. Susceptibility to Gully Erosion
- 21. The Universal Soil Loss Equations (USLE)
- 22. Soil Loss Tolerance
- 23. Rainfall and Runoff Factor (R)
- 24. Scope Length and Steepness Factor (LS)
- 25. Soil Erodibility Factor (K)
- 26. Cover and Management Factor (C)
- 27. Support Practice Factor (P)
- 28. Susceptibility to Wind Erosion
- 29. The Wind Erosion Equation
- 30. Conventional Agricultural Practices
- *31. Soil Fertility Improvement
- *32. Erosion Control
- *33. Erosion Control Facilities
- *34. Shrink - Swell Potential
- 35. Presumptive Bearing Value
- 36. Corrosion Potential
- 37. Trafficability/Bearing Strength of Subsurface Strata
- 38. Overflow/Flooding Hazard
- 39. AASHO + Unified Classification
- 40. Engineering Data (Properties)
- 41. Soil Analyses
- 42. Soil Maps
- 43. Water Seepage and Retaining Properties
- 44. Erosion From Human Activity
- *45. Rocks, Bedrock Composition
- *46. Soil Nutrient Deficiencies
- *47. Soil Toxicities

*B. Climatic Parameters
- *1. Air Temperature (monthly mean, max., min.)
- *2. Snowfall (monthly)
- *3. Snow Accumulation
- *4. Thunderstorm Patterns (monthly)
- 5. Sunlight Duration
- 6. Solar Radiation
- *7. Precipitation (amount)
- *8. Precipitation (distribution)
- *9. Precipitation (type)
- *10. Atmospheric Temperature Changes
- *11. Frost Free Period
- *12. Winds
- *13. Evaporation and Transpiration
- *14. Storms
- *15. Length of Growing Season
- *16. Average Date of First and Last Freeze
- 17. Degree Days Heating
- 18. Degree Days Cooling
- 19. Mean Number Days of Cloud Cover/Month
- *20. Precipitation (number of days)
- *21. Snowfall (number of days)
- 22. Per Month Freeze-Thaw Transition
- 23. Wind Chill Factor
- 24. Effect of Temperature Extreme on Equipment
- 25. Effect of Temperature Extremes on Transportation
- 26. Effect of Storms on Equipment and Transportation
- 27. Visibility Conditions
- 28. Altitude of Clouds
- 29. Humidity (seasonal patterns)
- 30. Humidity (daily patterns)

*C. Existing Structural Facilities
- 1. Corrals
- 2. Fencing and Gates (permanent + temporary)
- 3. Protective Barricades
- 4. Magazines/Igloos
- 5. Piers/Docks
- 6. Recreational Structures
- 7. Open Loading Docks
- 8. Flag Poles
- 9. Radio Towers
- 10. Mock Villages
- 11. Bunkers
- 12. Grandstands
- 13. Targets
- 14. Observation Towers

*Asterisks indicate parameters which potentially have the greatest impact on revegetative efforts.

Table 2 (Cont'd)

*C. Existing Structural Facilities (cont'd)

15. Revetments
16. Pits
17. Concrete Pillboxes
18. Launcher Sites
19. Ammunition Dumps
20. Radar Facilities
21. Dams
22. Airfield + Heliports (functional, abandoned)
23. Railroads
24. Walks
25. Sanitary Landfills
26. Telephone Network
27. Radio Network
28. Cemeteries
29. Roads -- 28 subunits
30. Buildings -- 18 subunits
31. Water System
32. Steam System
33. Sanitary Sewer System
34. Industrial Sewer System
35. Electrical Distribution System
36. Compressed Air System
37. Natural Gas System
38. Coal Storage Facilities
39. Fuel Oil Storage System
40. On Post Structural Resources -- 6 subunits
41. Artificial Waterways
42. Archaeological Sites
43. Windmills & Windpumps
44. Pipeline Pumping Stations
45. Transmission Lines & Substation
46. Cattleguards
47. Cultural & Historic Sites
48. Snow Removal (Roads, Walks, Cost)
49. Storm Safety Facilities
50. Transportation Fuel Storage Areas
51. Restoring Storm Damaged Facilities

D. Aquatic Biotic Parameters

1. Aquatic Plants
2. Phytoplankton Productivity
3. Aquatic Pest Plants
4. Fish Economic Value
5. Fish Undesirables
6. Fish Growth
7. Fish Parasites
8. Fish Population -- 8 subunits
9. Impact Fishing
10. Vehicular Damage
11. Invertebrate Fauna

E. Aquatic Natural Abiotic Parameters

*1. Lakes (location, size)
*2. Lakes (shoreline)
*3. Streams (location, size, flow)
*4. Lakes and Streams - 7 subunits
*5. Ground Water Resources/Table
*6. Watershed/Drainage/Discharge Characteristics
*7. Springs
*8. Marsh/Swamp (size & location)
*9. Eutrophication
*10. Suspended Solids
*11. Use by Fish & Wildlife
12. Tides
13. Inland Waterways
14. Coastal Waterways
15. Water Bodies Bordering Lands
16. Salt Water Types

F. Aquatic Man-Influenced Abiotic Parameters

1. Fishing Areas
2. Boat Launches
3. Swimming Area
4. Maintained Shoreline/Beaches
5. Reservoirs
6. Water Sites Shared With Non-Military Users
7. Steams (impoundments upon)
*9. Surface Water Contributions & Withdrawal
10. Water Quality/Pollution Levels
11. Impact of Grazing
12. Water Resources Value for Recreation
13. Domestic Water Availability for Recreational Areas
*14. Irrigation & Its Effects (Water Vegetation)
15. Amphibious Movement and Suitability
16. Water Rights
*17. Range and Maneuver Sites
*18. Projected Military Usage
19. Military/Agricultural Land Use Coordination
20. Impact/Restricted Area
21. Military/Fishing Coordination
22. Military/Outdoor Recreation Coordination
*23. Training Impacts -- 3 subunits

G. Terrestrial Natural Abiotic Parameters

1. Topographic Maps (20' contour)
*2. Terrain Analysis Maps
*3. Elevation
*4. Scope Length
*5. Slope Orientation/Aspect
*6. Land Form Variety

Table 2 (Cont'd)

G. Terrestrial Natural Abiotic Parameters (cont'd)

*7. Rock Form Features
8. Air Quality
9. Topographic Feature References
10. Subsurface Vibration Transmission
11. Mass Wastage (degree of instability)
12. Tectonic Activity
13. Sites for Sources of Engineering Materials
14. Sites for Valuable Subsurface Material
15. Atmosphere Impacts -- 3 subunits
16. Aerial Photographs

H. Terrestrial Man-Influenced Abiotic Parameters

1. Hunting Acreage
2. Campgrounds/#Units
3. Picnic Grounds/#Units
4. Off Road Recreational Vehicle (Type and Acreage)
5. Animal Salt & Mineral Distribution Points
6. Pesticides Program
7. Structures for Animal Habitat
8. Excavation Sites (Quarries/Pits)
9. Trails -- 8 Types
10. Herbicide Program
11. Firebreaks and Fire Control
12. Integrated Pest Management System
13. Noise Levels and Derivation (Training On-Post, Off-Post)
14. Burying Personnel Waste Materials
15. Excavating Trenches, Gun Emplacements, Foxholes *Fill, Road Surfacing, Earthworks*
16. Protected/Impact/Range Areas
17. Military/Forestry, Hunting, Agriculture, Recreation Coordination
18. Areas Restricted by Access or Noise

*I. Military Parameters

1. Weapon Systems
2. Electronic Combat
3. Types of Training Units
4. Tracked Vehicles
5. Wheeled Vehicles
6. Fixed Wing Aircraft
7. Rotary Wing Aircraft
8. Amphibious Vehicles
9. Water Craft
10. Cross Country Movement
11. Training Area Land Requirements
12. Other Training Unit Requirements
13. Engineering Restrictions to Excavations

*J. Terrestrial Animal Parameters

1. Game Animal Populations (general)
2. Non-Game Animal Populations (general)
3. Populations (Specific) -- 15 factors
4. Predator -- Prey Interactions
5. Avian Fauna
6. Migratory Species (waterfowl)
7. Mammal Fauna
8. Herpetological Fauna
9. Invertebrate Fauna
10. Threatened and Endangered Species
11. Parasites
12. Pathogens
13. Nesting Sites/Density

*K. Terrestrial Plant Parameters

*1. Critical Area
*2. Vegetative Pattern Diversity
*3. Type Vegetation
*4. Tree Size Class
*5. Overstory Density
*6. Forest Reproduction
*7. Ground Cover Density
*8. Pest/Poisonous Plants
*9. Pest/Weed Species
*10. Potential Natural Vegetation
*11. Species Composition
*12. Species Value
*13. Height Diversities
*14. Distribution of Vegetation
*15. Successional Stage
*16. Trees Growth/Yield
*17. Shrub Growth
*18. Grass Growth
19. Mast Production
20. Cavities
*21. Seasonal Variations in Vegetation
*22. Susceptibility to Fire
*23. Disturbance Tolerance
*24. Protected Species
*25. Vegetative Concealment
*26. Vegetative Cover
27. Forest Resource Maps
28. Forest Type Maps/Forestry Classification
29. Timber Sale Contract Parameters -- 15 subparameters
30. Forest Insect Protection Program
31. Forest Disease Protection Program
32. Forest Climatic Damage Data
*33. Plant Associations
*34. Temperature Survival Data
*35. Thermoperiodicity Data
*36. Light Tolerance

Table 2 (Cont'd)

K. Terrestrial Plant Parameters (cont'd)

*37. Moisture Tolerance
*38. Special Natural Range
*39. Special Population Data
*40. Natural Regeneration Potential
*41. Artificial Regeneration Potential/Methods
42. Forest Management Model

*L. Terrestrial Man-Influenced Biotic Parameters

1. Human Use of Range and Habitat
2. Impact Hunting and Trapping
3. Vehicular Damage
4. Wildlife Management Sites
5. Forestation Sites
6. Seeding
7. Burning
8. Brush Control
9. Mowing
10. Fertilization
11. Cultivation
12. Pruning
13. Agricultural -- 17 subparameters
14. Pests/Insects/Damage Control
15. Pests/Other
16. Predators/Control
17. Poison Levels in Animals
18. Feral Dogs/Cats
19. Wind Breaks
20. Impact of Browsing/Grazing
21. Forest Fire Protection
22. Trespass Data
23. Silvicultural Practices -- 5 subparameters

M. Terrestrial General Biotic Parameters

1. Habitat Composition
2. Special Features
3. Habitat Use (General)
4. Habitat Use (Ruminants)
5. Habitat Use (Birds)
6. Shoreline Habitat
7. Habitat Interface
8. Habitat/Edge
9. Open Field/Grass Habitat

N. Population/People Parameters

1. Total Family Income
2. Educational Level of Household
3. Place of Residence
4. Census Region
5. Age
6. Race
7. Sex
8. Marital Status
9. Family Size
10. Handicapped
11. Days Worked per Week
12. Vacation
13. Total Population in Influence Zone
14. Population Within (units of distance)
15. Travel Cost
16. Travel Time, Based on Population
17. Agricultural Demand for Land
18. Agricultural Cost & Benefits
19. Agricultural Leasing Agreements
20. Army-Unique Demands -- Housing, Postal Service, Recreation, Religious, Schools
21. Cantonment Facilities
22. Restricted Areas
23. Religion
24. Life Style
25. Transient/Permanent
26. Recreational Activities & Interests
27. Off/On Post Resource Demands
28. Displacement of Previous Users
29. On/Off Post Employment
30. Hunter/Trapper/Fisherman Attitudes & Values
31. Hunter/Trapper/Fisherman Economic Values
32. Storm Warning Procedures
33. Training for Storm Preparation
34. Hunter/Trapper/Fishing Quotas
35. Land Area Ownership
36. Land Area Control
37. Land Area Survey Data
38. Original Land Survey & Corner Data
39. Platt Books
40. Land Use/Zoning Data
41. Legal Description/Forestry Areas
42. Aims/Goals of Land Owner

O. Surrounding Area Parameters

1. Substitute Recreational Areas Within 300 miles
2. Travel Cost to Substitute Recreational Area
3. Travel Time
4. Fee Schedule for Substitute Recreational Areas
5. Quality of Substitute Recreational Areas
6. Off-Post Agricultural Land-Use
7. Off-Post Resources
8. Off-Post Land Use
9. Off-Post Fire Protection
10. Training Access Adjacent to Urban Settlement (noise)

land manager can use Table 2 as a guide to insure that adequate baseline information is available.

In the southwest, moisture is often the limiting factor in vegetative re-establishment. Thus, information about annual precipitation is critical. In these arid areas, the time, duration, and frequency of storms is often more important than average annual precipitation.

Soils data should include information on soil type, soil structure, infiltration rates, and nutrient availability. This information is critical for determining the type of plants most likely to survive. It will also determine whether soil amendments such as mulch or fertilizer will be needed. Irrigation requirements should be determined and topographical information in terms of altitude, slope, and aspect should be gathered. Information on average annual temperatures (highs, lows, and number of frost-free days) will also be needed.

Information should then be gathered on the operational constraints that will be placed on the maintenance or rehabilitation program. This includes information such as equipment availability, manpower, and funding. The ultimate use of the area will greatly affect the reclamation effort. Close liaison with the Training Officer will allow the land manager to produce an area that is both acceptable to training needs and sound land management practices.

Data must also be gathered on what activities will be on-going during the maintenance effort; i.e., whether the area will be closed to all training during the maintenance activities or whether some type of training will be allowed. The manager must also determine how soon training will begin after the maintenance activities have ceased in order to find out how long vegetation will have to establish itself.

Site Preparation

There are three major types of site preparation: (1) vegetation removal, (2) primary tillage, and (3) secondary tillage.

Removal of Vegetation

Vegetation removal is commonly used to remove undesirable species, such as mesquite, from rangeland in the southwestern United States. The information in this section emphasizes mechanical removal of undesirable vegetation. The four techniques described are roller chopping or brush cutting, chaining, root plowing, and disking (see Table 3). Neither chemical removal nor the use of fire is discussed as they are beyond the scope of this report.

Roller Chopping. Roller chopping is used to remove both large- and small-sized vegetation. For example, larger pinyon-juniper and chaparral are removed using a specially designed, self-propelled unit. The unit has a push-bar in the front to knock down the plants; it moves on drums which have chopping blades attached to break up the vegetation as it is crushed. In some areas, local residents remove the larger woody material for firewood, leaving

Table 3

Removal of Vegetation

Technique	Advantages	Disadvantages	Comments
Roller-Chop	- Eradicates large/small vegetation - Both self-propelled and towed units - Prepares seedbed	- Does not control sprouting vegetation	- Production - towed 2 to 9 acres (.8 ha/hr) - Towed units, slopes 35 to 70 %, (1 to 20% maximum for contour) - Self propelled unit, slopes up to 45%
Chaining, Cabling	- Controls large vegetation	- Not effective in controlling sprouting vegetation - Young plants with flexible stems not controlled - Difficult on rough or rocky terrain	
Root Plowing			- Blade severs plant roots and lifts to surface
Disking	- Primarily sagebrush control - Kills 30 to 100% of treated area	- Not effective in rocky soils	- Production rates are between 1 to 4 acres/hr

the rest of the material to decompose. A tractor-pulled drum with blades is used to remove smaller vegetation such as sagebrush or small pinyon-juniper.

When the unit is pulled across the vegetation, the drum pushes the plant down; it is then chopped as it is run over. The pieces left by these units are much smaller than those left by the self-propelled unit. Production rates vary from 2 to 9 acres/hr (0.8 to 3.6 ha/hr). Roller choppers function on a 35 to 40 percent slope, although 1 to 20 percent appears to be the maximum for towing on the contour. Self-propelled units handle slopes up to 45 percent. Chopping effectively controls nonsprouting vegetation, but does not control sprouting vegetation permanently. Also, the cutting blades can contribute to erosion or can be damaged by large rocks.

Chaining. Another technique to control large unwanted vegetation is chaining, cabling, or railing. Generally, this method is used to control mesquite, chaparral, sagebrush, and pinyon-juniper. This technique consists of attaching lengths of anchor chain, cables, or linked railroad ties to two tractors. The tractors drag the cable along the ground and uproot the vegetation, which is removed later. Without additional treatment, this technique is not effective for controlling sprouting plants and does not control young plants with flexible stems. It is difficult to control vegetation on rough terrain with this technique. Cables, which are less flexible than chains, tend to lose ground contact easily.

Root Plowing. Root plowing is commonly used to remove chaparral and mesquite. The root plow is a U-shaped, horizontal blade 4 to 6 ft (1.2 to 1.8 m) across attached to the back of a crawler tractor and pulled 8 to 16 in. (.2 to .4 m) below the surface. The blade severs the plant roots and lifts the plant to the surface.

Disking. Disking is primarily used to control sagebrush. The disk, which is pulled behind a tractor, cuts and lifts vegetation and at the same time inverts it. Disking generally destroys 80 to 100 percent of the treated area -- both desirable and undesirable vegetation. Production rates of between 1 to 4 acres/hr (.4 to 2 ha/hr) have been recorded. This method is effective in sandy soils, but not in rocky ones.

The techniques discussed in this section deal primarily with water retention. They are designed to increase the water available to plants by increasing the amount of infiltration and the soil's water-holding capacity. Seven methods (see Table 4) are discussed: (1) pitting, (2) dozer basins, (3) gouging, (4) land imprinting, (5) ripping, (6) chiseling, and (7) contour furrowing.

Pitting. Pitting, which disturbs one-third of the area, is the creation of depressions and basins 4 to 8 in. (.1 to .2 m) deep, 8 to 12 in. (.2 to .3 m) wide, 24 to 30 in. (.6 to .75 m) long and spaced 18 in. (.45 m) apart. The pits are dug by pulling a modified one-way disk across the soil. The disks (wheels) are cut so that they touch the ground only during part of a revolution. Weight can be added to the implement to allow penetration of varying soil types.

Table 4

Water Retention Techniques

Technique	Advantages	Disadvantages	Comments
Pitting	Can be used on a variety of soil types	Cannot be done on rocky soils	
	Only one-third of the area disturbed	Can only be used on slopes less than 8%	
	Traps water evenly over an area	Water-piping has occurred on shallow soils	
	Controls grasses and weeds	Loses most of its effectiveness in 1 year	
Dozer Basins	Reduced competition	Expensive	
	Can be constructed on steeper slopes and rockier soils than pitting		
Gouging	Differential snow melt	Slopes less than 20%	
	Can be done on rocky ground		
Land Imprinter	Adjustable to different soil types	Not capable of treating dense or sprouting vegetation	Production rates of 4 acres (1.6 ha/hr) Slopes to 45% can be imprinted
	Firming action prevents splash and sheet erosion	Repeated treatments may be necessary	
	Run-over vegetation left as mulch		
	Works well on rough, rocky, or brush-covered terrain		

Table 4 (Cont'd)

Techniques	Advantages	Disadvantages	Comments
Ripping	Can be used on soils too rocky to pit or disk	Expensive Soil piping	Most effective on silt loam soils
	Breaks compacted soil into clods	Saturation of silts can occur	
	Can break up clay layer	Does not prepare an adequate seedbed	
		Can pull large rocks to the surface	
		Slits may reseal too quickly	
Chiseling	Breaks up soil without inverting it	Effective only on relatively flat ground	Will prepare seedbed for broadcast seeding
	Effectively mixes amendments with soil	Can move rocks to surface	
		Effects are temporary	
Contour Furrows	Works well on heavy soils	Expensive	
		Furrows overtopped at low point, resulting in gully formation	

Pitting has been successful for range reseeding and controls grasses and weeds fairly well, since it destroys one-third of the competing vegetation directly. Other competing vegetation is controlled when it is buried under the soil scooped out of the pits; this reduces the emergence of annual grasses and weeds. Pitting is economical and effective on relatively flat, rock-free soil.

The main disadvantage of pitting is that the slope and type of soil may restrict the areas where it can be used effectively. It is not a functional technique on even moderately rocky soils and is not recommended on slopes greater than 8 percent because of the probability of gullying. Pitting is also not recommended on shallow soils, where water piping may occur if the pitter head penetrates the parent material. It is recommended that pitting be done approximately on the contour. Generally, pitting is a short-term operation, since it loses much of its effectiveness after the first year.

Dozer Basins. Dozer basins give the landscape the same basic appearance as pitting, but on a larger scale. The basins are created by a small dozer which creates small depressions about 2 ft (60 cm) deep in the soil. The width of the basin depends on the blade's width. The basin length varies.

Dozer basins give the same benefits as pitting. Water collects in the depressions and percolates into the soil, making more water available to the plants. Competition is reduced where the soil has been piled by burying competing vegetation. The equipment used allows dozer basins to be built on steeper slopes and rockier soils than pitting.

Basins are also created by crawler tractors using a basin blade. This is a crescent-shaped blade, which is attached to the rear of the dozer and is 9.8 ft (3 m) long with a depth to 3 ft (91 cm). Large depressions are formed along the contour by periodically raising and lowering the blade. It is best suited for use on slopes.

Gouging. Gouging is done using a towing implement consisting of heavy steel knives attached to a solid bar. The bar is spring-loaded where it is attached to the frame; this allows operation in rocky soils. The knives, which are raised and lowered, create depressions that are 6 to 10 in. (15 to 25 cm) deep, 15 to 21 in. (38 to 56 cm) wide, and 3 to 4 ft (.9 to 1.2 m) long. Like pitting and dozer basins, these depressions are desinged to trap and retain moisture. Gouging also results in differential melting of snow in the spring. The snow in the depression melts last, so moisture is available to plants longer. Gouging, which was designed for slopes of 20 percent or less, works best on gentle slopes or relatively flat areas. It can be done on fairly rocky ground. One study done in Montana showed that gouging reduced moisture stress significantly, since it allowed more water to be stored in the upper 4 ft (1.2 m) of soil than chiseling or dozer basins; thus, gouging resulted in greater plant survival than either of the other two techniques.[7]

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[7] Richard L. Hooder, "Montana Reclamation Problems and Remedial Techniques" in Principles and Problems of Land Reclamation in Western North America (University of North Dakota Press, 1975), p 93.

Land Imprinter. The land imprinter is a towed drum with raised designs which leave impressions in the soil. It can be filled with water to adjust the weight to different soil types. The depression created can collect up to 5 cm of rainfall and disperse concentrated runoff, thus controlling erosion. The firming action of the machine helps prevent splash and sheet erosion. The run-over vegetation is left on the ground as mulch. Imprinting works well on rough, rocky, or brush-covered terrain and on slopes up to 45 percent. The imprinter cannot treat dense stands or sprouting brush. Repeated treatments may be necessary if the impressions wear down. Production rates of more than 4 acres (1.6 ha/hr) have been reported.

Ripping. Ripping opens slits in the soil which allow aeration and water percolation. It is usually done by a crawler tractor pulling a wheeled implement which has two or three prongs or teeth mounted 3 to 5 ft (.9 to 1.5 m) apart. Some rippers are mounted on tow bars attached to the rear of a dozer. Others have rotating augers mounted above and below the teeth or prongs.

Ripping is used for two purposes: to break heavily compacted surface soil into smaller clods, and to break subsurface clay layers. Generally, rangeland is ripped on contour with 30- to 50-ft (9- to 15-m) spacings between the strips.

Ripping is designed to retain water and increase infiltration. It is often used on lands that are too rocky to pit or disk. In experiments in the Rio Puerco Drainage Basin, ripping was found to be more effective than pitting in reducing erosion over a 3-year period.[8] Ripping was most effective on silt loam soils, but did little to reduce erosion on clayey soils on south slopes.

Ripping has four disadvantages: (1) it is expensive because of the heavy equipment required; (2) if the parent material is penetrated by the ripper, water piping may occur; (3) in areas where the subsoil is impermeable, saturation of the slit can occur, causing plants to die due to lack of oxygen; (4) it does not prepare an adequate seedbed, since it leaves the soil in large clods and brings large rocks to the surface. The soil must then be reworked with a chisel or disk to break up the larger clods.

Ripping should be done when the soil is relatively dry, so that the desired layer is shattered. If the soils are ripped when they are too wet, the slits may reseal quickly. If it is suspected that the slits may become saturated, they can be mulched vertically (i.e., mulch is placed in the slit). This will prevent the soil from becoming water-saturated.

Chiseling. Chiseling, which is used to break up the soil without inverting it, destroys plant roots and loosens the soil. Chiseling is effective only on relatively flat slopes and should be done on the contour. It breaks the surface, catches and holds rainfall, and resists wind erosion. This technique will prepare the seedbed for broadcast seeding, as well as for effective mixing of amendments with the soil. Chiseling has two major disadvantages:

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[8] Wayne C. Hickey, Jr., and E. J. Dortigal, "An Evaluation of Soil Ripping and Soil Pitting of Runoff and Erosion in the Semi-Arid Southwest," Land Erosion, Precipitation, Hydrometry, Soil Moisture, Publication No. 65 (International Association of Scientific Hydrology), p 27.

(1) it can move rocks to the surface, which will interfere with secondary tillage, and (2) its effects are temporary.

Contour Furrows. Contour furrows are furrows plowed along the contour and can vary widely in both depth and spacing. The smallest, which may be 3 to 4 in. (.07 to .1 m) deep, 6 in. (.15 m) wide, and closely spaced, are used on more permeable soils where runoff is light. The largest are 12 in. (.3 m) deep, 18 in. (.45 m) wide, widely spaced, and are used on heavy soils. Small basins are created in furrows that are slightly off the contour by placing check dams at 6- to 8-ft (1.8- to 2.4-m) intervals. This prevents water from running into low places in the furrow, so the water spreads more evenly over the soil. The contour furrows work well on heavy soils with large amounts of runoff, because they can store great amounts of runoff.

Contour furrows have some disadvantages. The furrows are costly to install, because the size and placement of the furrows must be planned carefully. The equipment requires relatively smooth terrain to operate properly and safely. Sometimes water will overtop furrows at a low point, causing gully formation.

Fertilization

Secondary tillage involves breaking up the large clods left after primary tillage for eventual planting using a disk or harrow. It firms the soil, eliminates air pockets, kills weeds, conserves moisture, and is used to incorporate fertilizer and other soil amendments.

There are three basic types of secondary tillage implements: disk harrows, roller harrows, and tooth-type harrows. Disk harrowing works well for seedbed preparation. Roller harrowing (called cultipacker, cultimulcher, soil pulverizer, or corrugated roller) breaks up clods with the front wheels. The harrow then brings up more clods, which are broken up by the rear wheels. This method is particularly good for preparing soils for range drills (see pp 44 to 45). The most versatile secondary tillage operation is tooth-type harrowing, which can loosen soil crust and dig, lift, and break clods.

Fertilization/pH Control

Fertilization and pH control are highly interrelated (see Figure 1). Therefore, pH must be considered when determining the nutritional needs of the plants to be grown. Generally, soils in the southwest are alkaline (pH >7). Although certain plants may tolerate a wide range of pH, they may grow best within a more narrow range because of the secondary effects of pH. The microfauna of the soil will also be affected by the pH. For example, at certain ranges, the effectiveness of the mycorrhiza of the plant may be reduced. Also, pH may increase or decrease the incidence of disease caused by microorganisms.

pH Control

Soluble calcium salts, acid formers, or acid with no carbonates can be used to lower the pH of the southwest's alkaline soils. Examples of soluble calcium salts include calcium chloride -- for short-term immediate effects --

G. SIGNIFICANCE OF SOIL REACTION (pH) ON PLANT NUTRIENT AVAILABILITY

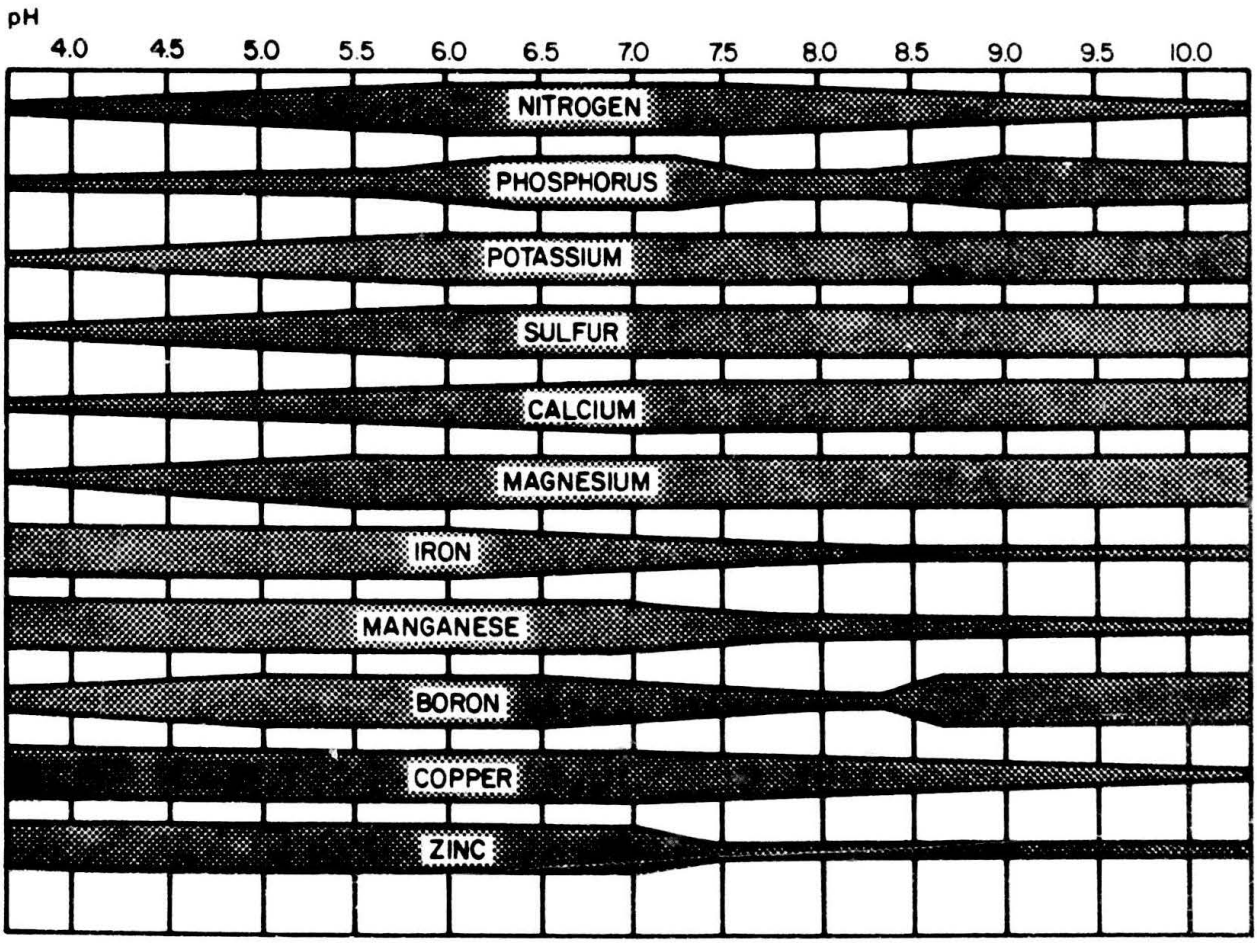

Figure 1. The general relation of pH to the availability of plant nutrients in the soil (the wider the bar, the more available is the nutrient). (Adapted from Emil Truog, USDA Yearbook of Agriculture [U.S. Department of Agriculture, 1943-1947].)

and calcium sulfate (gypsum) -- for long-term effects. The greater solubility of calcium chloride accounts for its shorter-term effects. Addition of acids will also reduce soil alkalinity. However, care must be taken when adding acids to soils which contain no alkaline earth carbonates to avoid forming an acid soil. Commonly used acids are sulfur, sulfur acids, iron sulfate, aluminum sulfate, and lime sulfur. Sulfur and sulfur acids are used on lime soils.

Excessively acidic soils can be treated by adding either organic matter or lime. Lime is added in the form of ground limestone (calcium carbonate), burnt lime (calcium oxide), calcium hydroxide, or lime residue from sugar beet processing. The type of limestone added depends on how long-lasting an effect is desired. Ground limestone (aglime) is used for a long-range effect, because it is not as soluble as calcium oxide or calcium hydroxide, which have immediate but short-term effects. Liming of acidic soils has several other

advantages. It adds calcium to the soil, improves the soil's physical condition, releases nitrogen by decomposing organic matter, increases fertilizer efficiency, and decreases the toxicity of aluminum and ferric ions.

Fertilization

The need to fertilize depends primarily on the plants' nutrient requirements and the soil's current condition, as indicated by testing. The decision to fertilize depends on the deficiencies within the soil, the necessity to fertilize, the cost, and the available soil water.

Fertilizer is generally applied to supply the three basic nutrients: nitrogen, phosphorous, and potassium. Nitrogen is more important to plant productivity than to seedling development. It encourages above-ground growth, is important to plant enzymes, increases protein content, and promotes succulence. Nitrogen is available from a number of sources, including soil organic matter, rainfall, residue, manure, and nitrogen-fixing plants (see Table 5). Due to the instability of nitrogen, soil tests are of limited value in determining deficiencies. Some indication of a nitrogen deficiency can be found by examining plants growing on the site. The plants' leaves will be fired (starting at the base, the edges of the leaves will show a yellowish, dried-up color). The plant may also be stunted and its foliage chlorotic. Since these symptoms may also be shown in other situations, soil and plant tissue tests should be done to confirm nitrogen deficiency.

It has been recommended that 40 to 50 lb (16 to 20 kg) of nitrogen per acre be applied to disturbed sites. Sources include ammonium nitrate (33-0-0),* ammonium sulfate (20-0-0), ammonium phosphate (11-48-0, 21-53-0), sewage sludge (variable), or manure.

Because nitrogen interacts with other soil constituents, it must be applied at the correct time to be available to plants. If late fall seeding is done, it should be applied in the spring after germination. If spring seeding is done, it should be applied at the time of seeding. Nitrogen should not be allowed to contact the seed. Since nitrogen is very soluble, it may be surface-applied. Nitrogen fertilization has a short-term effect; therefore, repeated applications may be needed.

Table 5

Common Nitrogen Fertilizers

Ammonium nitrate	33-0-0*
Ammonium sulfate	20-0-0
Ammonium phosphate	11-48-0, 10-53-0
Sewage sludge	
Manure	

* Percent composition of nitrogen, phosphorous, and potassium.

Seedling development requires large amounts of phosphorous. Deficiencies are indicated by purplish leaves, stunted growth, and low reproduction. Soil tests are a reliable method for indicating phosphorus deficiencies.

It has been recommended that 100 lb (40 kg)/acre of phosphorous be applied to coarse textured soils and 200 lb (80 kg)/acre to fine-textured soils. Common sources of phosphorous include triple superphosphate (C-46-0), superphosphates (0-22-0), ammonium phosphate (11-48-0, 10-53-0), diammonium phosphate (11-48-0, 21-30-5), sewage sludge, or manure (see Table 6). Neutral and calcareous soils should be treated with the soluble forms, such as superphosphate and ammonium phosphates.

Phosphorous should be mixed into the soil before seeding in such a way that it is available to the seed. Phosphorous is best banded or used as a pop-up fertilizer. Its application should be long-lasting; generally, only one application is needed to start phosphorous cycling, assuming that no crop is removed.

Potassium -- the third major nutrient -- is important for general tone, vigor, and disease resistance. Potassium deficiencies are indicated by leaves which appear dry and scorched at the edges, and by stunted plants which are easily blown over. Potassium tests are reliable for deficiencies. The most common source of potassium is potassium chloride (0-0-60).

Soils may also lack other nutrients. These are usually required only in small amounts and should be applied based on the plants being grown.

The fertilizer application method depends on the fertilization requirements and type of equipment available. Common methods include banding, deep drilling, plowing, drilling with seed, foliar application, side dressing, bedding, starter solutions, top dressing, and irrigation. Of equal importance to site preparation is the correct selection of plant species, plant materials, and planting techniques. Without this, the best-prepared site will be unsuccessful.

Table 6

Common Phosphorous Fertilizers

Triple superphosphate	0-46-0
Superphosphate	0-22-0
Ammonium phosphate	11-48-0, 10-53-0
Diammonium phosphate	18-46-0, 21-30-5
Sewage sludge	
Manure	

Species Selection

Choosing the correct species can be a complex process. Not all plant species are adapted* to all sites or uses, and many elements influence adaptability. Being able to identify adapted species is important, because the ability of a species or ecotype to adapt to a specific site is a major step in successful site rehabilitation.[9]

Some plants do not have to be adapted. Such plant species are used as nurse or companion crops. These are usually annuals that may be planted prior to or with the permanent species; they temporarily stabilize the site and help establish the permanent species. Nurse or companion crops are usually used when they can help stabilize the land or improve soil characteristics more quickly. Researchers disagree about the usefulness of nurse crop species. Some have successfully planted harsh sites with a nurse crop of a species that will persist several years; others have found nurse crops undesirable because their excessive competition delays or reduces permanent seedling establishment. In the latter cases, initial seeding with primary, adapted species capable of plant colonization was more successful.[10]

A third type of temporary crop is the "preparatory" crop. It is generally seeded before the perennial species. The perennial is then seeded directly into the residue of the preparatory crop, with no further seedbed preparation. Preparatory crops apply better to dry climates than nurse or companion crops (see Table 7).[11]

Criteria To Consider When Selecting Adapted Species

Military land managers must consider four major attributes in selecting plant species to be used for rehabilitation: wear resistance, regrowth potential, erosion resistance, and multiple-use potential.

Wear resistance reflects the ability of the plant to withstand the effects of foot and vehicular traffic through an area. The greater the wear resistance, the more training can be performed.

Regrowth potential includes both an individual plant's ability to recover quickly after being damaged and the ability of a species to quickly reinvade an area after destruction by training exercises.

In the Southwest erosion resistance is more concerned with loss through air movement than water. There, desirable plants must be able to hold soil during wind storms and the infrequent rainstorms.

Multiple-use potential is another critical concern for the military land manager. After the requirements for military training are met, he/she must

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* A plant's ability to complete its entire life cycle and replace itself in succeeding generations.

[9] User Guide to Vegetation, Mining and Reclamation in the West, p 13.

[10] User Guide to Vegetation, Mining and Reclamation in the West, p 65.

[11] User Guide to Vegetation, Mining and Reclamation in the West, p 65.

Table 7

Companion and Preparatory Crops -- Their Advantages and Disadvantages
(From User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining [SEAM] Program, General Technical Report INT-64 [USDA, Forest Service, 1979], p 26.)

Item	Companion Crops	Preparatory Crops
Advantages	Reduces wind and water erosion	Protects topsoil until a permanent species can be established
	Reduces weed competition	Controls wind and water erosion
	Protects forage species from wind and severe temperatures	Reduces evaporation from around seeds and establishing plants
	Will produce a crop of value prior to development of perennial forage species	Smothers out germinating weeds
		Reduces or prevents a new crop of weeds
Disadvantages	Can result in severe competition for moisture and light required by the desired perennial forage species	Reduces seed contact with mineral soil if residue is too thick
		Some cases of phytotoxins left from preparatory crop residue
		Can provide competition from volunteer seedlings if preparatory crop permitted to produce seed
Comments	Not recommended for semiarid or arid regions where moisture shortages are likely during establishment period, or on soils of low fertility	In general, preparatory crops have more application in dry climates of West
	Especially beneficial in sub-humid and humid regions or with irrigation	
	Where irrigation is available, competition will be lessened; however, irrigation also increases chances of success of desired vegetation, even without companion crops. In this case, companion crop has advantage in windy or high temperature sites.	

attempt to get the best combination of other uses -- i.e., conservation, recreational, aesthetic, and economic -- from the land. For example, military land managers are encouraged to make economic use of the land by using it for grazing if possible.

Six other factors should always be considered when selecting species:[12] growth form, drought resistance or tolerance to stress, mineral nutrition requirements, reproduction characteristics, availability of seed, and competition among species. Other factors which should be considered are discussed below:

Rehabilitation Objectives. These relate to the plant's function, e.g., training realism, wildlife habitat, crop, rangeland forage, beauty, or recreation.

Nature of the Site. The following[13] characteristics must be considered when determining the nature of the site.

1. Plants must be adapted to the soil. Soil characteristics that should be examined include pH, fertility, texture, depth, permeability, presence of toxic materials, and water retention capacity. Generally, topsoil is the best plant medium, because it has the fertility and physical conditions needed for plant growth; however, in some cases subsoils may provide better plant productivity than topsoil. These subsoils are carbonaceous shales or clay loams, rather than silty clays. Fertilization may be needed in these exceptional cases.

2. Plants must adapt to both the amount and seasonal distribution of local precipitation. For example, shrubs adapt to droughty and saline sites because of structure and physiology of their roots and foliage.

3. Plants must be adapted to the local temperature, including daily maximums, daily minimums, and averages.

4. Elevation is often important. It often affects the length of the growing season. Generally, as elevation increases, the growing season decreases.

5. The site's slope is important. Deep-rooted species should be used when shallow-rooted plants are not suitable for stabilizing steep hillsides. Slope angle mostly influences soil stability and the amount of incident solar radiation received.

6. Plants should be adapted to aspect. Plants that do well on an eastern exposure may not be able to grow on the northern side of the same hill.

7. Local wind velocities may cause severe water stress in plants and may affect growth habit, pollination, and structure.

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[12] User Guide to Vegetation, Mining and Reclamation in the West, p 15.
[13] User Guide to Vegetation, Mining and Reclamation in the West, pp 14-16.

8. Other factors which must be considered include potential fire risk, invasion of weed, and animals.

Timing. Species should be planted to coincide with expected moisture; a fast-rooting species should be used where erosion control is important.

Species Compatibility.[14] Generally, mixtures of various adapted grasses and forbs are desirable because they can offer a greater range of adaptation; e.g., grasses and forbs protect against surface runoff and erosion more quickly than do shrubs and trees. However, shrubs and trees provide protective cover and food for certain wildlife. Some examples of mixtures are: warm season and cool season grasses; fast-growing and slow-growing grasses; and forbs and grasses.

An exception to this rule is mixing annuals and perennials, because this can sometimes cause competition problems. This practice may be risky if annuals force out perennials. If they are mixed, 10 percent or fewer annuals should be used to avoid competition. Two other approaches are to seed competing plants in alternate rows or strips, or to scalp and then interplant shrubs and trees to reduce grass competition.

Mechanical Limitations on Planting. The selected species should either lend itself to commonly used planting methods or a planting method should be developed for it.

Maintenance After Planting. If it is important to plant a persistent perennial species, use low-maintenance plants, since maintenance can be very costly. The low-maintenance species would be:[15]

- Self-generating
- Long-lived
- Disease-resistant
- Pest-resistant
- Require no refertilization
- Require no irrigation

There is, of course, no one species that has all these characteristics. The next best thing to do is to review the characteristics and determine which are the most important in terms of cost, time, and manpower. These characteristics should have priority when species decisions are made.

Cost. The cost of seed is usually low when compared to the cost of grading and seedbed preparation. Containerized stock, bare-root stock, and seeds of native plants are usually more expensive than commercial seed varieties.

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[14] User Guide to Vegetation, Mining and Reclamation in the West, p 15.
[15] User Guide to Vegetation, Mining and Reclamation in the West, p 16.

After considering all these criteria, several approaches can be used to select the correct species:

1. Referring to baseline information (temperature, precipitation, soils, etc.) about the site.

2. Relying on the experience of others.

3. Directly observing old disturbed sites on which revegetation has occurred naturally.

4. Referring to information available from researchers.

While the experience of others is useful, direct observation of previously disturbed areas having characteristics similar to the area being rehabilitated is probably a more reliable way to identify successful species. Observation should focus on species which have naturally adapted to the disturbance and provides information on natural selection and plant succession.

Generally, it is wise to start looking at early successional species because they will more actively colonize a disturbance. (If the exact species is not known, primary successional species are generally the first ones that appear on a disturbed site.) Observation of sites that are just beginning to be revegetated will help identify these species.[16] Where the site conditions are more favorable, the rehabilitation may start at later successional stages. The following are good sources of information on species selection:

1. The National Agricultural Library in Beltsville, MD.

2. Hybrid Breeding Program - Crops Research Laboratory, Utah State University (UMC-63), Logan, UT 84322.

3. The Plant Information Network (PIN) (see Appendix C).

Plant Material To Be Used

After determining the plant species to be used, the next step is deciding what type of plant materials are to be used and how they can be stored. There are a variety of types of plant materials, including seeds, bare-root or containerized seedlings, cuttings, sprigs, rhizomes, plugs, and wildings. Plant material selection depends on site requirements and expense. Normally a variety of stock should be used.

Seeds. Seeds are generally the least expensive plant materials. They are normally used when the species germinates easily and enough moisture for germination is expected. Usually 7 to 10 days in a moist, warm soil are needed for the seeds to germinate and establish. Other site conditions must be conducive to seeding. If erosion is a severe problem, especially in arid conditions, transplants may provide more effective ground cover than developing seedlings.

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[16] User Guide to Vegetation, Mining and Reclamation in the West, p 16.

Seeds can be obtained from a variety of sources; however, not all sources will be satisfactory. If the environmental conditions differ from those where the seed was collected, this can affect a seed's success.[17]

Seed need not be purchased locally if dealers in other areas have developed a seed source that better meets the installation's needs. For specific suggestion, Soil Conservation Service (SCS) personnel, county agents, State agricultural experiment stations, or other rehabilitation specialists can be contacted.

Typical seed sources include:[18]

Plant Material Centers. Centers sponsored by the SCS have developed improved plant varieties (Appendix A).

Commercial Seed Suppliers. After SCS develops and tests plants, seeds are made available to private growers who produce the seed and sell it through major seed companies. When purchasing seed, information on the seed source and germination tests done at official seed-testing centers should be requested.

Private Collectors. These are small local businesses that collect native seeds. These collectors will work under contract to harvest seed for specific projects. Lists of these collectors are available from the SCS, State universities, and Forest Service offices.

Personal Collection. If other sources do not have the required species, seeds can be collected fairly quickly from native stands. It is not uncommon for one person to collect 200 to 300 lb (80 to 120 kg) of fourwing saltbush seed in a day. Appendix B contains more details on seed collection.

Container-Grown Stock. Generally, container-grown stock is recommended for harsh sites or where a fast-developing ground cover is important. It is often used on rocky sites, sites with toxic soils, or sites where establishment is difficult due to erratic or low precipitation.

Container-grown stock will often succeed better than direct seeding. It bypasses the time from seeding through germination, emergence, and early growth and thus establishes the plant quickly.[19]

There are several disadvantages to using containerized stock. It is considerably heavier than other plant material, which may present shipping and handling problems. Container stock is also harder to maintain between the time that it is delivered to the time that it is planted. The plants require proper storage areas, watering facilities, and daily care. Cost is another

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[17]User Guide to Vegetation, Mining and Reclamation in the West, p 19.
[18]User Guide to Vegetation, Mining and Reclamation in the West, pp 19-20.
[19]User Guide to Vegetation, Mining and Reclamation in the West, p 22.

consideration. Containerized stock is more expensive than seed and will require more time and manpower to plant and maintain during severe dry spells.

Time is also a factor. Generally, the plants must be hardened before planting. If possible, container stock should be stored outside through one winter season. If seedlings are started in a greenhouse during the winter, they may only be 8 to 10 weeks old when planted. Such young plants should be "hardened off" for at least 2 to 3 weeks before planting by exposing them to cool weather and watering them less.[20]

Bare-Root Stock. Bare-root stock or nursery-grown stock is usually grown in beds for 1 to 2 years. The plants are dug up when dormant and the soil shaken from their roots; they are then packaged in moist peat moss in crates. The plants can be stored in coolers for as long as 1 year.

Bare-root stock is a way of establishing a fast-growing cover and is cheaper than container-grown stock. These plants are easier to ship, plant, store, and handle. Most native shrubs and trees can be successfully grown and planted as nursery stock.[21]

Despite the positive aspects of bare-root stock, two major disadvantages may keep the Army from using them extensively: they take longer to cultivate and they must be removed from the nursery and planted in specific seasons.

Cuttings, Rhizomes, and Sprigs. Cuttings are pieces of stems, usually from woody plants; they are either rooted and then planted directly on the site, or directly cut and then planted. Cuttings can provide ground cover in a short period of time if species are adapted to this type of cultivation and there is enough moisture for plant establishment. Cuttings must be acquired in season and handled according to established practices for the various species.[22]

Sprigs and rhizomes are normally taken from herbaceous plants and started in containers or flats. Rhizomes are underground stems of grasses, sedges, or forbs that can be rooted and replanted. Sprigs are pieces of grasses or sedges that can be rooted and dug up and then replanted on another site.

Wildings and Plugs. Wildings are individual plants transplanted from the wild to another site. Plugs are usually field-grown, native clumps of vegetation which have been dug up and replanted on another site; plugs may contain several plants. These plant materials are useful when a species already adapted to the site does not produce an adequate seed crop.[23]

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[20] User Guide to Vegetation, Mining and Reclamation in the West, pp 22-23.
[21] User Guide to Vegetation, Mining and Reclamation in the West, p 24.
[22] User Guide to Vegetation, Mining and Reclamation in the West, pp 24,26.
[23] User Guide to Vegetation, Mining and Reclamation in the West, p 26.

Planting

This section discusses different types of planting methods.[24] Before choosing the planting method, the correct planting time must be determined.

The time to plant will vary according to climate, type of planting stock and soil, moisture needs of the species, frost heaving problems, anticipated erosion problems, and sufficient dryness to allow equipment onto the site. A general rule to follow is that planting times should coincide with the most favorable period of moisture or the longest precipitation season so that enough moisture is available to establish seedlings or transplants. To help determine the best time to plant, the land manager should examine the baseline data dealing with the area's climatic regime and several years of temperature/precipitation relationships. Tables 8 through 11 are timing matrices for different areas of the West and show the advantages and disadvantages of different planting methods in different seasons.

Planting Seeds

Seeds can be planted by drilling or broadcasting. Seeds planted by drilling are dropped from a seeding machine into holes or furrows and then covered with earth. Broadcasting scatters the seed on the ground's surface; the seeds may or may not be covered with earth. Both drilling and broadcasting can be done with machines or by hand. Table 12 compares drilling and broadcasting.

Where site conditions permit, drilling is the better method, because the seed is covered to a proper depth, distribution is uniform, rate of seeding is controlled, and soil firming can be done with packer wheels attached to the drill.

Broadcasting is less efficient because the seeds often perch on top of the soil where germination and establishment are difficult, if not impossible. Broadcasting requires 50 to 75 percent more seed to provide a stand comparable to one produced by drilling.[25] Broadcasted seed should always receive some mechanical treatment to give it suitable coverage unless the bed is so loose that natural sloughing of soil will cover the seed. Planting should be done on the contour to trap available moisture and prevent erosion. On slopes too steep for planting equipment and where ripping has been done on the contour, planting may have to be done up and down the slope; however, some erosion may be caused by wheel tracks if this method is used.

Types of Equipment

This section discusses types of equipment commonly used for revegetation in the southwest (Table 13).

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[24] User Guide to Vegetation, Mining and Reclamation in the West, p 35.
[25] Revegetation Equipment Catalog, p 105.

Table 8

Time to Plant, Northern Great Plains Timing Matrix
(From User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining [SEAM] Program, General Technical Report INT-64 [USDA, Forest Service, 1979], p 26.)

	Spring		Summer		Fall[1]		Winter	
Activity	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages
Direct seeding[2]	Most optimum conditions probable between early March and late April. Seedlings must emerge before start of spring rains. Topsoil receives best protection at this time	Access can be a problem		Optimum planting conditions have passed--would require irrigation. Postpone seeding to fall	Provides best access and weather for planting. Stratification important to native and shrub seed. More time available to plant	Topsoil and seedbed protection a problem		Seeding on snow is possible but wind may destroy seedling. Seedbed preparation and access are difficult
Bare root	Essential to plant early between frosts and snowstorms so that roots will develop before buds break dormancy. Plant immediately prior to maximum soil moisture season	Timing is very critical		Storage a problem. Seed dormancy broken. Soil too dry. Plants will burn. Lack of necessary moisture	Plants can be planted when dormant and become better acclimated to site if planted after frost	Some species not adapted to fall planting	Not recommended	
Containerized	Most optimum conditions exist very early in spring between frosts and snowstorms	Disadvantage is that stock is usually not ready or available. Access sometimes a problem	Not recommended		Same as above	Same as above	Not recommended	

PROVIDED BY R. C. HODDER

Climate Summary: Considered a continental climate, with warm summers and cold winters. Temperatures can range from -40°F to +105°F. Average precipitation about 12 inches, but can vary from 4 to 18 inches annually in various localities. Precipitation dependent on snowmelt and spring rains that fall between April and mid-June. High wind and high evaporation rates common.

[1] Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.
[2] Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded soils where natural sloughing will cover the seed.

Table 9

Time to Plant, Alpine Timing Matrix
(m User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining [SEAM] Program, General Technical Report INT-64, [USDA, Forest Service, 1979], p 26.)

Activity	Spring	Summer		Fall[1]		Winter
		Advantages	Disadvantages	Advantages	Disadvantages	
Direct seeding[2] (grasses, sedges, forbs)	Sites not accessible	None	Optimum site conditions have already passed. Site may remain too dry. Seed not yet ready to be collected	Provides for dormancy requirements. Site conditions are usually optimum in fall (e.g., not too wet). Seed will be in place next spring when conditions are optimum	Seed collection of natives may coincide with optimum planting times. Seeds may have to be collected 1 year ahead, or purchased commercially from nurseries. If seeding is too early, frost damage to germinating seedlings may occur	Sites not accessible
Bare-root stock	Not recommended in this life-zone					
Containerizer tubelings or native plugs (grass, sedges, forbs, and some shrubs and trees)	Sites not accessible	None	Actively growing plants may not be hardened-off to low temperatures. Conditions not favorable	Plant only after dormancy is induced. Site conditions are usually most favorable	Frost thrusting may lift plants if not firmly packed. High risk of severe storm activity	Sites not accessible

PROVIDED BY R. W. BROWN

Climate Summary: Short growing season of 45 to 80 days; low summer temperatures averaging about 43°F, high wind speeds, high solar radiation loads, and no frost-free periods (needle ice thrusting can occur at any time). Seasons of summer and fall are compressed into about 2 months, and winter and spring together are about 10 months.

[1]Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.
[2]Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

Table 10

Time to Plant, Great Basin Range and Foothills, and Colorado Plateau Timing Matrix
(From User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining [SEAM] Program, General Technical Report INT-64, [USDA, Forest Service, 1979], p26.)

	Spring		Summer		Fall[1]		Winter
Activity	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages	
Direct seeding[2]	Favorable temperature/ precipitation for seedling establishment	Late winter may reduce time available for seeding. Late frost or a short spring may reduce seedling establishment or growth	Not recommended		Seeds may receive needed cold treatment and germinate in late winter	Early winter may prevent completion of seeding operations	Not recommended
Bare-root planting	Plant can establish if planted before summer drought	A short spring season may reduce survival	Not recommended		Plant mid-fall. Avoid late fall planting	Frost heaving in heavy soils. Open winters	Not recommended
Transplanting container-grown plants	Best results for establishment are in spring. Hazards of seed germination and establishment are bypassed	Weather may be a problem in scheduling field work	Possible if can be planted in moist soil. Long period of planting is possible	High temperatures and drought can be detrimental	Best results for establishment. Plant early to mid-fall	Frost heaving. Open winters	Not recommended

PROVIDED BY CY McKELL

Climate Summary: An area of isolated mountain ranges and extensive level valleys where a highly variable frost-free growing season may be from 120-180 days in the valleys and less than 110 days in the foothills. Spring and fall temperatures are generally moderate (50°F), but high summer temperatures may reach in excess of about 98°F. Warm season precipitation from erratic thunder-showers is less than half of the total precipitation of about 6-16 inches annually.

[1]Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.
[2]Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

Table 11

Time to Plant, Semi-Arid Timing Matrix
(From User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining [SEAM] Program, General Technical Report INT-64, [USDA, Forest Service, 1979], p26.)

	Spring		Summer		Fall[1]		Winter	
Activity	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages
Direct seeding[2] (grasses)	Cool season species only	Winter moisture variable	Warm season species. More reliable precipitation. Plant prior to July-Aug rains	None	None	Frost heaving. Limited fall growth	None	Unsuitable for germination and growth
Bare root (shrubs)	Not recommended		Plant after initiation of summer rains. Soil moisture must be near saturation	Timing critical. Variable precipitation	If summer rains are late, early fall plantings are possible	Frost heaving	Not recommended	
Containerized seedlings (shrubs)	Not recommended		Soil moisture must be near saturation	Variable precipitation	If summer rains are late, early fall plantings are possible	Frost heaving	Not recommended	

PROVIDED BY EARL ALDON

Climate Summary: Semiarid mesas and valleys of northwestern New Mexico and northeastern Arizona are characterized by low, highly variable rainfall and high summer temperatures. Highest rainfall months are July and August with occasional late summer storms extending to September. Driest months are May and June. Rainfall varies with elevation, but in lower areas averages 7-10 inches annually. Snowfall light most years and seldom remains on ground. Growing season ranges from 140-180 days.

[1]Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.
[2]Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded soils where natural sloughing will cover the seed.

Table 12

Seeding Methods Advantages/Disadvantages

(From User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining [SEAM] Program, General Technical Report INT-64, [USDA, Forest Service, 1979], p26.)

Characteristics	Drilling		Broadcasting			
	Machine	Hand	Hydroseeding	Other Machines	Hand	Aerial
Topography	Steep slopes and access are problems; if slopes are greater than 3:1, broadcasting recommended	Less limited	Can handle steep terrain, depending on distance	May be limited by steep terrain	Less limited	Unlimited
Obstructions	Limits use	Unlimited	Unlimited	Somewhat limited	Unlimited	Unlimited
Compacted Soil	Possible	Possible	Not acceptable	Not acceptable	Not acceptable	Not acceptable; soil must be rough enough for wind and rain to cover seeds
Seeding Depth	Variable and controlled	Variable; somewhat less controlled	Lays on top of the soil	No direct control; depends on soil	No direct control	No direct control
Seed Size	Variable if drills can be adjusted	Variable if hand-held machines can be adjusted	Small seed	Variable	Variable	Variable
Season	Limited by moisture	Limited by moisture	Limited by low expected moisture	Less limited	Less limited	Less limited
Precipitation	Slightly critical	Slightly critical	Very critical; more success when annual precip. exceeds 12-14 inches	Very critical	Very critical	Very critical
Soil Texture	Not critical	Not critical	Critical	Critical	Critical	Critical

Table 12 (Cont'd)

Characteristics	Drilling		Broadcasting			
	Machine	Hand	Hydroseeding	Other Machines	Hand	Aerial
Seed Distribution	Uniform	Uniform if person is well trained; seeds can be precisely placed	Less uniform	Less uniform	Not uniform but can be specific to one area	Not uniform
Mulching	Separate treatment	Separate	Same treatment possible but not advised	Separate	Separate	Separate
Cost	Medium	Depends on how many people needed	High	Low	Depends on number of crews needed	Low if surface area to be covered is extensive
Equipment	Special in some cases	Some hand-held equipment available	Scarce	Available	Some hand-held equipment available	Various types available; can be contracted out
Seed Rate	Less than broadcasting; drastically disturbed sites such as spoils require much heavier seeding rates than do sites where topsoil and some plant cover are intact. Examples: 10-15 lb/acre drilled on north-facing gentle slopes with small grass seed; 25-30 lb/acre if species seed is large; 40-45 lb/acre if conditions are severe, such as south-facing steep slopes	Same as machine drilling	More; as much as double the drilling rate	More	More	More; 1/3 more than drilling
Trash in Seeds	Must be cleaned from seeds	Must be cleaned from seeds	Cleaning not critical	Cleaning not critical	Cleaning not critical	Cleaning not critical
Time required/acre to seed	Middle range	High range	Low range	Low range	High range	Lowest

Table 13

Seeding Equipment

Equipment	Capacity	Limitations
Seeder Cultipacker	Plants in rough terrain. Can be used for covering seed that was broadcast.	
Rangeland Drill	Adapted to seeding rough rocky terrain. Capacity to control small brush or annuals used in areas having been burned or chemically treated. Can plant a variety of seeds at varying rates. Seeding depth is easily controlled. Furrows control erosion and aid in seedling establishment.	Row spacing may be too wide for some applications. Limited operating ability in areas with heavy brush or trash. The better the seedbed preparation, the more efficient the drilling operation. Slopes too steep for contour operation should not be drilled. Difficult to transport without special equipment and techniques.
Pasture Drills	Designed for grass seed. Many can drill fluffy or chaffy seed effectively. Are more sturdily built than most grain drills.	Competition problems between newly sown seed and existing vegetation. Most are not suited for rough, rocky, or brushy areas.
Oregon Press Seeder	Useful in dry, loose soil. Seeder can operate in fluctuating terrain over rocks and brush.	Not designed for heavily compacted soils, or as a deep furrow.
Range Interseeders	Can seed grass, forbs, or shrubs in areas w/o previous seedbed preparation. Can be used in sandy or silty soils. Forage quantity and quality can be increased w/o eliminating original vegetation.	Competition for moisture may limit establishment and maintenance of interseeded plants on dry sites. Livestock must be carefully managed to prevent overgrazing. May be difficult to operate on clay soils because of soil crusting and sticking. Not well suited to steep, rough, or rocky areas.
Interseeder for Rocky and Brushy Areas	Can plant smooth, fluffy, or trashy seed on rough, rocky terrain. Furrows control competing vegetation, increase moisture availability, and reduce reinvasion until plants can be established.	Contours should be followed closely on steep terrain to reduce erosion hazard. Grazing should be controlled.
Steep Slope Seeder	Plants seeds on very steep slopes.	
Blower Spreader	Models available that will broadcast both fluffy and slick seed or fluffy seed only. Uniform distribution achieved with minimum seed damage.	Fluffy, light broadcast seed may drift on windy days.
Hydro Seeder	Fast, efficient means of large-scale seeding in steep, hard-to-reach areas. Application rates can be varied to suit conditions. Mulch can be applied.	Demands large amount of water. Possible seed damage by agitators and pumps. Mulching should be done separately.

Table 13 (Cont'd)

Equipment	Capacity	Limitations
Aerial Seeding		
Fixed Wing	Can rapidly seed or fertilize large areas. Can quickly and effectively treat areas having slopes, soil conditions, or terrain features that limit ground equipment.	Requires air strips. Does not allow precise placement of broadcast materials. Materials may be moved by wind or water after application. Seed may be damaged during application.
Helicopters	Able to treat large, remote areas, rugged terrain, and steep slopes. Can be reloaded or refueled from a truck parked near area being treated. Very maneuverable at low flying speeds.	Similar to fixed-wing aircraft. Uniform distribution of materials difficult. Most of material is deposited in center of swath.
Seed Dribblers	Can accomplish seeding during control operation. Problems with wind and water movement are reduced.	Seed placement is restricted to crawler tracks. Tracks may be disturbed by towed implements. May take several years for plant cover to expand onto adjacent areas.
Grass Seeder	Plant seed at proper depth on a firm, smooth seedbed. Soil is firmed around seed, and small furrows help direct infiltration. Two hoppers can broadcast two types of seed and fertilizers in one pass. Produces a uniform stand when plants mature.	Requires thorough seed bed preparation. Not suited for use in rough, rocky, or brushy areas. Small furrows wear down quickly during severe weather.
Tree Spades	Transplant trees and shrubs with minimum root damage and soils disturbance. Cone-shaped four-blade configurations allow deeper penetration, but the three-blade models can generally operate faster.	Use is limited to slopes of 15% or less. Trees with extremely long tap roots cannot be successfully transplanted with a tree spade.

Drilling.

Seeder-Cultipacker. This type of drill is also called the grass-seed planter or seeder-packer drill. The seeder-cultipacker has a fluted feed which meters seed from the hopper. The seedbed is prepared in previously tilled soils by the front rollers which break up clods. Seeds are then dropped in furrows formed by the front rollers. Rear rollers split the rows, cover the seeds, and compact the soil around them. This seeder is designed for planting grasses and legumes and can be used in rough terrain as long as it can be operated safely. It can also be used for covering broadcasted seed.[26]

Rangeland Drill. The rangeland drill is a heavy-duty, side-wheel drill having large wheels, a high-clearance reinforced frame, and single-disk openers independently suspended on trailing arms. The trailing arms have skid plates underneath to prevent breakage. Heavier, deep-furrowing arms are also available. The furrows are covered with drag chains or 2-in.- (5-cm) diameter pipe drags, 42 to 48 in. (107 to 122 cm) long. The 20-in. (51-cm) disk openers can be equipped with 14-in. (36-cm), 16-in. (41-cm), or 18-in. (46-cm) depth control bands.

The drill can be equipped for deep-furrow drilling with special deep furrowing arms and heavy-duty 24-in. (61-cm) disks. The disk angles can be adjusted on deep-furrowing arms to better control small brush and competing annuals in the furrows. Other available options include a small-seed hopper attachment, a fertilizer attachment, a brush guard to protect the running gear, and steel wheels for areas with numerous brush snags where rubber tires cannot be used. The drill can be modified for reduced seeding rates and large-scale chemical applications. Half-size, or 5-ft (1.5-m) models are also available.[27]

The rangeland drill can be operated on areas with or without previous seedbed preparation; however, heavy brush should be removed to reduce damage and delays. Production rates average 2.5 to 5.0 acres (1 to 2 ha) per hour for rubber-side wheels and about half that rate for steel wheels. Furrow depth can be controlled with the depth bands or by adding weights to the trailing arms. Pipe drags are attached during deep-furrow drilling to pack the soil in the furrows. The furrows provide shelter and increased moisture for the seed and seedlings. The rangeland drill can seed two species and apply fertilizer at the same time.

The rangeland drill is useful for seeding rough, rocky terrain. It can control small brush or annuals and is often used in areas that have been burned or chemically treated. The rangeland drill can plant a variety of seeds at widely varying rates. Seeding depth is easily controlled, and the furrows control erosion and aid seedling establishment.[28]

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[26]User Guide to Vegetation, Mining and Reclamation in the West, pp 39-41.
[27]User Guide to Vegetation, Mining and Reclamation in the West, p 118.
[28]Revegetation Equipment Catalog, p 116.

This method has some limitations. The row spacing may be too wide for some applications. If the drill is used in areas with heavy brush or trash, equipment will break, causing excessive downtime. The drilling operation becomes more efficient with better seedbed preparation. Slopes too steep for contour operation should not be drilled. The rangeland drill is difficult to transport without special equipment and techniques.

Pasture Drills. The pasture drill is a heavy-duty drill designed for seeding grass in stubble or pastures having no prior seedbed preparation. The drill sows grass or grain directly into stubble, pasture, or grassland and is designed for minimum tillage. The coulters or openers penetrate the surface trash or mulch and place the seed into the underlying soil. Depth bands are available to regulate seeding depth, and press-wheels firm the soil. The seeding rates are adjustable.

Pasture drills are specifically designed for grass seed, and many of them drill fluffy or chaffy seed effectively. Pasture drills are more sturdily constructed than most grain drills.[29]

There are limitations associated with competition between the existing vegetation and the newly planted seeds for moisture and soil nutrients. Such competition may be too severe for seedlings to become established without previous seedbed preparation. A limitation of the drill itself is that most pasture drills are not suited to rough, rocky, or bushy areas.

Oregon Press Seeder. The Oregon press seeder seeds grasses in light, loose soils. It was developed for soils associated with big sagebrush (Artemesia tridentata) in Oregon. The seeder places seed in a firm seedbed and covers it with loose soil.

The seeder is made of 12 heavy steel press-wheels, 32 in. (810 mm) in diameter with a 6-in. (15-cm) tread, each independently suspended. A 1-in. (2.5-cm) V-shaped ridge in the center of the head creates furrows for the grass seed. Seed-metering devices and a hopper from a standard grain drill are mounted on top of a heavy-duty frame. Coil spring seed tubes place the seed in furrows and conventional drag links close the furrows and cover the seed. Moisture is made available for root growth in the packed soil, while leaf growth remains unobstructed by the loose covering. Ditches should be crossed at an angle to prevent damage to the seed tubes.[30]

The Oregon press seeder is useful in dry, loose soils that are commonly found in sagebrush bunch grass areas. Independent suspension allows the seeder to follow terrain fluctuations and operate over rocks and brush.

This seeder is not designed for heavily compacted soils or as a deep furrow drill. The rangeland drill is more trouble-free than the Oregon Press Seeder in rough terrain.

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[29] Revegetation Equipment Catalog, p 116.
[30] Revegetation Equipment Catalog, p 119.

Range Interseeder. The range interseeder is designed to improve existing stands of vegetation in areas where complete seedbed preparation is impractical or undesirable. They can operate on the contour to increase moisture availability and prevent erosion.

The interseeder works by creating wide, shallow furrows in the ground; seed is then planted in the center of the furrow. These wide furrows eliminate competitive vegetation and provide shelter and increased moisture for establishing seedlings. The vegetation remaining between the furrows prevents erosion and shades the furrows. Check dams can be created by briefly lifting the range interseeders from the soil while moving along the contour.

Range interseeders can seed grass, forbs, or shrubs in areas without previous seedbed preparation. Forage quantity and quality can be increased within a few years without eliminating the original vegetation.

Interseeders are most often operated in sandy soils but may be used in silty soils. Competition for moisture may limit the establishment and maintenance of interseeded plants on very dry sites. Livestock must be carefully managed on interseeded areas to prevent overgrazing. Range interseeders may be difficult to operate on clay soils because of soil crusting and sticking. They are not well-suited to steep, rough or rocky areas.[31]

Interseeder for Rocky and Bushy Areas. Because the range interseeder does not work well in rough or rocky areas, the Forest Service Equipment Development Center designed an interseeder especially for rough rangeland conditions. It can create deep, wide furrows, seed a wide variety of plants, and operate effectively on rocky and brushy ground. This seeder can plant smooth, fluffy, or trashy seed on rough, rocky ground. The furrows control competing vegetation, increase moisture availability, and usually reduce reinvasion until the plants can be established. Contours should be followed closely on steep terrain to reduce erosion, and grazing should be controlled to insure successful plant establishment.[32]

Steep-Slope Scarifier Seeder. This planter is a combination drill and broadcaster which can plant seeds on very steep slopes. It is attached to the end of a hydraulic crane and extendable boom. The seeder's tynes rough up the surface, the seed and fertilizer is broadcast, and dirt drags cover the seed. The soil is packed over the seed with independently suspended press wheels. This seeder is capable of effectively planting seeds on steep, easily eroded soils. The seeder is also able to plant over debris piles, stumps, rocks, or other obstacles. Debris can be left as protective mulch for the seedlings. Since the seed is well-covered and not carried away by wind or water, uniform stands can be established on slopes of 45 to 75 degrees.

The seeder is not capable of incorporating mulch. This will have to be done by other methods. Currently, the seeder can only be mounted on telescoping

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[31] Revegetation Equipment Catalog, p 122.
[32] Revegetation Equipment Catalog, p 119.

boom cranes; however, a separate hitch that would enable the seeder to be towed behind other large vehicles is being developed.[33]

Broadcasting.

Centrifugal-Type Broadcasting. This type of broadcaster is also called an end gate seeder. It provides an economical method of seeding most varieties of seeds, as well as applying granular and pelletized fertilizers. Generally, centrifugal-type broadcasters have an effective spreading width of about 20 to 40 ft (6 to 12 m), depending on the seed's physical characteristics. Hoppers are available that hold from 75 to 2000 lb (30 to 800 kg) of seed or fertilizer.[34]

Field Distributor. Also known as a full-width feed broadcaster, the field distributor is made up of a seed box with metering devices along its full width. It does not have furrow openers or seed covers. Two separate operations are needed to prepare the seedbed and cover the seed.

Fan or Airblast Seeder/Rotary Spreader. This type of seeder/spreader can broadcast seed, fertilizer, or granular pelletized herbicide. Seeder/spreaders consist of a hopper that feeds the material into one or two revolving fans or spinners. The rate of flow is determined by the size of the hopper opening. The material is distributed in a fan-shaped pattern that can be adjusted for density or direction.

Seeder/spreaders can be mounted on tractors or other vehicles. There are also some that are hand-held and operated. This type of seeder is simple and reliable. It works well in combination with other implements. The hand-held models have no terrain limitations and are good for spot treatment.

The major problem with the seeder/spreader is that it does not allow precise or uniform distribution of materials. Materials that are broadcast are subject to movement by wind or water after they are applied, and they are subject to damage while being broadcast.[35]

Blower Spreader. The blower spreader is a type of fan or airblast seeder designed to broadcast seed during mechanical treatment; it can be mounted on trucks or tractors. The seed is broadcast from the blower spreader while the land is being treated mechanically. The mechanical action prepares the seedbed or covers the seed.

Some of these machines will broadcast both fluffy and slick seed or fluffy seed only. The blower diffuser system provides uniform distribution with minimum seed damage. The broadcast density is adjustable. The major

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[33]Revegetation Equipment Catalog, p 111.
[34]User Guide to Vegetation, Mining and Reclamation in the West, p 41.
[35]User Guide to Vegetation, Mining and Reclamation in the West, p 41.

limitation of the blower spreader is that the light, fluffy broadcast seed may drift on windy days.[36]

Hydroseeder. The hydroseeder applies seed with a high-pressure stream of water. The seed must be covered with soil or mulch in a separate operation to insure germination and establishment. The seed can be covered by harrowing, disking, or using a small sheepsfoot roller. The hydroseeder can also apply mulch. If seed is applied with a mulch, the seed need not be covered with soil because the water/mulch mixture will act as a soil covering.[37]

The hydroseeder, or hydraulic seeder-mulcher, consists of a tank, a pump powered by a separate engine, and a discharge nozzle assembly. The tanks are equipped with various types of agitators to assure uniform mixtures. Large centrifugal pumps can spray the mixtures up to 200 ft (61 m) and have particle clearances of up to 1-1/2 in. (3.8 cm). Interchangeable discharge nozzles provide several spray patterns. The nozzle assemblies can rotate a full 360° horizontally and from 120° to 180° vertically to provide complete coverage. Hydraulic seeder-mulchers may be mounted on either a trailer or truck frame.

To apply seed, the tank is filled with a slurry containing 3 to 6 percent solids by weight. The operator sprays the mixture over the area, controlling the spray pressure and volume. The hydraulic seeder-mulcher may be operated while stationary or moving. A separate hand-held hose can be used for small-scale or spot treatments.

Hydraulic seeding is a fast, efficient way to do large-scale seeding in steep, hard-to-reach areas. Application rates may be varied to suit conditions. Mulch can be applied to increase the soil's moisture-holding capability and to reduce erosion.[38]

One disadvantage of this method is that it requires large amounts of water, which may not always be available. Another limitation is that the agitators and pumps may damage the seeds. Seeding and mulching should be done separately so that the seed is not held off the ground by mulch fibers.

Aerial Seeding. Aerial seeding is advantageous where the terrain is too rough to use surface equipment; it can be done with either fixed-wing aircraft or helicopters. It may often be possible to use land equipment such as a chain to roughen up the area, but the site may not be tilled enough to allow drilling. Aerial seeding allows free movement among sites. It can be used when the land manager wants to introduce more species to the area without disturbing the vegetation already growing there.

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[36]Revegetation Equipment Catalog, p 109.
[37]User Guide to Vegetation, Mining and Reclamation in the West, p 43.
[38]Revegetation Equipment Catalog, p 110.

1. Fixed-Wing Aircraft. Aerial spreaders are either rotary spreaders or venturi-type, ram-air spreaders. The higher airspeeds of fixed-wing aircraft are best suited to venturi-type spreaders; rotary broadcasters are suited to slower airspeeds or lower application rates. Both types of seeders have a hopper inside the fuselage with a sliding gate to control application rate which is operated from the cockpit. An agitator within the hopper insures a continuous flow of materials. The rotary spreaders are powered hydraulically or electrically. Venturi-type spreaders use the propeller slipstream to blow the materials out the back and to the sides of the spreader.[39]

The equipment is calibrated for the desired application rate. Overlapping swath patterns are flown over the treatment area to give fairly even coverage. Spotters or markers are used to note previously treated areas and area boundaries. The plane should be flown as low as possible to minimize drift.

There are several disadvantages to using fixed-wing aircraft for seeding. First, the aircraft require airstrips for take-off and landing. In addition, aerial broadcasting at high speeds does not allow precise placement of materials. The materials may also be moved by wind or water after application. Seed may be damaged during the operation or destroyed by animals later. Finally, much of the seed may be wasted because it is not placed on a microsite that allows germination.[40]

2. Helicopters. Most helicopter spreaders are rotary spreaders attached to both sides of the helicopter or suspended beneath it. The spinners are powered hydraulically from the helicopter engine or with a separate gasoline engine. Other helicopter spreaders are the aerial hydraulic seeding system and the blower spreader. Application rates are determined by the size of the hopper opening, which is controlled by the pilot. The hoppers have agitators which insure a constant flow of materials. The load can be jettisoned quickly in an emergency.

The flow of seed is calibrated to provide a specific application rate at a given airspeed. The pilot applies the material by carefully controlling the flow through the hopper openings. The spinners distribute the material over a broad swath; however, some overlap is desirable for even distribution. The helicopter should be flown as low as possible to prevent drift. Markers or spotters should be used for precise applications.[41]

Helicopters can treat large, remote areas, rugged terrain, and steep slopes since they require no landing strip, can be reloaded or refueled from a truck parked near the area, and are very maneuverable at low flying speeds.

Their limitations are similar to those of fixed-wing aircraft. For example, uniform distribution of material is difficult. In addition, most of the material is deposited in the center of the swath, and the amount of overlap is difficult to determine accurately.

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[39] Revegetation Equipment Catalog, p 105.
[40] Revegetation Equipment Catalog, p 105.
[41] Revegetation Equipment Catalog, p 107.

Seed Dribblers. Seed dribblers are small, traction-driven broadcasters that mount on a crawler tractor above the tracks and have either fluted-force-feed or spoke-and-thimble metering mechanisms. The fluted-force-feed is similar to the metering devices in most grain drills. The spoke-and-thimble device has small cups attached to spokes that rotate through the seed in the hopper. Both metering devices are adjustable to the type of seed and seeding rate being used.[42]

The seed dribbler mounts on the crawler tractor and dribbles seed onto the track. The seed is then carried on the track, dropped to the ground, and pressed into the soil by the tracks. The compacted soil provides a good, firm soil bed to hold moisture and enhance plant establishment and growth.

This device is useful for seeding during the control operation. Since seed is pressed into the soil, problems with wind and water movement are reduced.

The major limitation of the seed dribbler is that seed placement is restricted to the crawler tracks. Several years may be required for plant cover to expand onto the adjacent areas. Tracks may also be disturbed by towed implements.

Grass Seeder. A grass seeder (i.e., seed cultipacker) has a seed box spreader mounted between two standard cultipackers. The spreader has two hoppers. The cultipackers have closely spaced, V-shaped grooves, about 1 in. (2.5 cm) deep. The grooves of the two cultipackers are offset to cover the broadcast seed. The first cultipacker smooths and firms the seedbed while creating several small furrows. The seed is broadcast into the furrows from the spreader. The second cultipacker fills in the original furrows and creates new ones between the rows of seed. The miniature furrows created by the second cultipacker firm the soil around the seed and help direct infiltration. The closely spaced rows produce a uniform stand of mature plants. The two hoppers can broadcast either two types of seed or both seed and fertilizer in one pass.[43]

The grass seeder has several limitations. It requires thorough seed bed preparation, and it is not suited for use in rough, rocky, or brushy areas. In addition, the small furrows wear down quickly during severe weather.

Other Stock

In most cases, seedlings should be planted by hand. A number of hand-held planting tools have been developed, but limited success has been achieved using this equipment built to plant bare-root stock. Since sprigs and rhizomes are usually cultivated as tubelings, they should be planted in the same way as other container-grown stock.

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[42] Revegetation Equipment Catalog, p 108.
[43] Revegetation Equipment Catalog, p 114.

There are two general rules for machine and manual planting methods:

1. Machine planting is only efficient if a large number of plants can be placed in long, continuous rows, the terrain is suitable, and the machinery will not destroy the site preparation design.

2. Manual methods must be used when site preparation includes surface-shaping treatments that would be damaged by subsequent machine operations, such as contour furrowing, gouging, or land imprinting. Also, hand methods should be used when the terrain is very steep or the area is so rocky that proper machine planting would be hard. Hand planting is also necessary when plants will be set in groups or clumps or when complex, mixed plantings of several species are made.[44]

Planting Container Stock. When planting container-grown stock, handle the stock as described on pp 33 to 34. Make holes for the stock with a mattock, auger, or dibble punch. To determine the proper depth of the hole, look at the size of the root system and the depth of the plant container. Remove the plant from the container, and plant the seedling carefully, keeping the root plug intact; then, firm the soil around the plant to eliminate any air space.[45]

Planting Bare-Root Stock. To eliminate air pockets, bare-root stock must be placed so that the roots are well-distributed and firmly in contact with the soil. The stock should not be spaced less than 1-1/2 times the diameter of the mature plant. Density should not be expected to be greater on revegetated sites than on undisturbed sites.

When risk of failure is high, cross-wind furrowing and mulching are recommended to conserve moisture;[46] also, trickle irrigation systems should be used to provide supplemental moisture for one or two growing seasons.

Seedling Planters. Seedling planters are tractor-drawn implements that open furrows for bare root or shrub seedlings and pack the soil around the seedlings after they are placed. As the planters are pulled over the area, the operator places the seedlings directly in the furrow or into the placement arms on semi-automatic planters. Various devices provide even spacing, or the seedlings can be planted at irregular intervals. Planting rates commonly average from 1000 to 1500 seedlings per hour.

These devices plant large numbers of seedlings quickly and consistently. They provide increased survival because they allow for deep root penetration and adequate soil compaction.[47]

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[44] User Guide to Vegetation, Mining and Reclamation in the West, p 44.
[45] User Guide to Vegetation, Mining and Reclamation in the West, p 44.
[46] User Guide to Vegetation, Mining and Reclamation in the West, p 44.
[47] Revegetation Equipment Catalog, p 125.

Seedling planters may be limited by site or terrain conditions. They are not suited to slopes greater than 20 percent and cannot operate over large obstructions such as stumps, logs, or large rocks. Another limitation is that the seedlings are planted linearly, and the furrows may contribute to erosion or frost-heaving. Also, bare-root stock may not be able to absorb enough moisture, particularly on arid sites, because most of the fibrous roots are destroyed during the transplant process.

Cuttings. Cuttings can be planted either rooted or unrooted. Unrooted cuttings should be planted only when favorable soil moisture and temperature are expected for at least 30 to 45 days. Cuttings should be planted before they have broken dormancy and with a minimum of the top exposed (less than 2 in. [50 mm] of the 1-ft-long [.3-m] cutting). When cuttings have been rooted in a greenhouse, they can be planted like container-grown stock.

Trees with trunk diameters of 1.5 in. (37 mm) or less can be planted like cuttings. The soil should be packed closely around the cuttings so that there is good contact with the soil and no air space. Tree cuttings are recommended whenever the species adapts to cutting (willows and poplars) and when there is enough moisture for them to become established. Cuttings as long as 4 ft (1.2 m) can be planted. Tree cuttings can also be planted earlier in the year than other kinds of stock.[48]

Wildings and Plugs. Wildings and plugs are two types of plant stock that can either be transplanted directly from their natural habitat to the site or, if nurtured in the greenhouse, in the same way as container-grown stock.

When plugs are dug from native vegetation, they can be planted manually on the site. The soil should be packed tightly around the roots to eliminate air space. Nursery-grown plugs and wildings can be planted similarly; however, a planting bar or dibble is recommended over a shovel.

Trees. Tree seedlings are planted as explained on p 53. Clumps of trees can be transplanted using a front-end loader or a tree spade.

The front-end loader is efficient for digging up and moving pads of shrubs or shallow-rooted trees, such as aspen. The pads must be replanted in an upright position, and guy wires may be needed to anchor the trees. Trees which attract wildlife may need to be fenced until they are established.[49]

Tree Spades. Tree spades have been developed for replanting small to medium-sized trees. The spade mechanically digs, balls, transports, and replants trees and is available in different sizes. It is powered by its own gasoline engine, and the four digging blades are hydraulically operated. The largest of the spades will handle trees that are about 5 to 6 in. (125 to 150 mm) in diameter and will take a ball that is about 66 in. (1.65 m) in

[48]User Guide to Vegetation, Mining and Reclamation in the West, p 46.
[49]User Guide to Vegetation, Mining and Reclamation in the West, p 48.

diameter on the surface. Shrubs have also been transplanted successfully using the tree spade.

The spade can be towed with a 3/4-ton, 4-wheel-drive pickup which has a tank to supply water to the tree spade's lubrication system. A complementary trailer has been developed that will carry eight tree transplants. When the tree spade is used, it is best to plant the tree in a hole that is larger than the tree ball, so that a small depression will be left after planting. This depression will catch available moisture.[50]

The tree spade has several disadvantages. Its use is limited to slopes of 15 percent or less, because the digging platform must remain level to insure that the tree is planted with its trunk vertical. Another disadvantage is that it cannot transplant trees with extremely long tap roots successfully.

General Principles of Mixed Seeding

If different sizes of seeds are planted together, the equipment used must be adapted to mixed seeding. Seed rates should be determined based on seed sizes, purity, handling, and mixing capabilities.[51]

Broadcast seeding accommodates different sizes and shapes of seeds; it is useful if the seeds are covered in a subsequent operation.

Several types of drills can also be used. The rangeland drill, which has two attached seed boxes, allows two seed sizes to be planted simultaneously (i.e., one type of seed is fed through each box). If a mix of seeds is drilled, it must first be cleaned of trash to allow the seed to go through the drill. Proper seeding rates can be attained by adding carriers, such as rice hulls, to the seeds; this will dilute or help regulate seed distribution.

Competition can become a problem if the mixed seeds have different germination rates and periods of emergence. One way to minimize competition is to drill individual plant species in alternate rows. Spot seeding or site-specific seedings can also be done; however, these techniques usually require hand-planting. Interseeders can be used to scalp away topsoil where there is weed competition. The desired species can then be seeded in the furrows made by the interseeder. Another method would be to drill grass seed in a site during one operation and interseed with other species later.[52]

Mulching

Mulches are any material applied to the surface layer of the soil. They include straw, hay, and oil (Table 14). Mulches have several purposes, but are used mainly for erosion control and to provide a proper micro-habitat for establishing vegetation. Other uses include water retention, temperature

[50] User Guide to Vegetation, Mining and Reclamation in the West, p 48.
[51] User Guide to Vegetation, Mining and Reclamation in the West, p 48.
[52] User Guide to Vegetation, Mining and Reclamation in the West, p 48.

Table 14

Advantages and Disadvantages of Commonly Used Mulches

Type of Mulch	Advantages	Disadvantages	Comments
Crop residues: straw or hay	Generally most economical	Weed seeds usually present; even hay seeds may be considered a weed on a particular site	Anchor mulch, especially on slopes by crimping or by using plastic meshes, jute, chemical tackifiers
	Usually satisfactory under many circumstances	Straw may "wick-out" moisture from soils in very dry conditions, resulting in poor germination and seedling establishment	Long-stemmed best, especially for crimping
			Uniform application important
			Generally, 2 tons/acre are adequate
			In Utah, it was found that rotovating mulch 6 to 8 in. into soil increased grass seedling survival
			Can be spread with modified farm manure spreader
Native grasses; prairie hay	Adds desirable native species seeds to area and mulches at same time	May harvest weeds along with native species	
Wood residues: sawdust, woodchips, bark, shavings	Protects surface	Shavings and sawdust blown	Chips: 2 tons/acre usually adequate; chip size, 1/2 to 1/50 in.
	Adds organic matter No weed seeds	Nitrogen deficiency	
	More fire resistant than straw	Packing may occur resulting in less aeration	
	Long-lasting	May float on running water	
	Easy to apply	May prevent precipitation from reaching spoil	
	Chips resistant to wind movement		

Table 14 (Cont'd)

Type of Mulch	Advantages	Disadvantages	Comments
Plastic film	Excellent vapor barrier Good weed control Light-colored, perforated, found effective in New Mexico: soil temperature in summer 18°F lower than in soil with no mulch	Labor-intensive High cost	Information on temperature effect varies Color is important because of reflection, absorption
Fiber tackifiers and soil binders	SBR Styrenebutadiene and SS Super Slurper have been found to be very absorbent and thus *help provide water*	Quite expensive Must be applied correctly in order to have maximum effectiveness With SBR Styrenebutadiene and SS Super Slurper, premature germination may occur In high wind areas, it can solidify, break into pieces, and blow away	Typically added into water carriers; can also be added with seed slurries 500 to 1000 lb of solids/acre usually sufficient; dilution rates of 5:1-7:1 optimum
Rocks, gravel, pebbles	Effective at specific sites Are permanent -- do not disintegrate	Smaller than 1/12 in. in diameter; not good for wind erosion	Choose sizes greater than 1/12 in. in diameter Must nearly cover entire ground surface -- 1 to 2 in. thick is effective control (135 tons/acre = about 1 in. depth)
Mixtures	Add micro-organisms to soil over short and long term (Ex.: straw and bark)		

Table 14 (Cont'd)

Type of Mulch	Advantages	Disadvantages	Comments
Hydraulic mulching	Labor costs low Typical green color allows operator to get uniform distribution Hydromulching and hydroseeding can be done at the same time, if it is impossible to do the two operations separately Wood cellulose fiber mixed with seed and fertilizer can be sprayed on steep slopes	Of little value unless it adheres to the soil surface and remains intact during rainstorms, wind Hydromulch with fiber improves germination, but does not improve production When hydromulch and hydroseeding are done together, seeds may not have adequate soil contact	Application rate of 1500 lb/acre appears adequate for most situations; may need more for quite steep slopes May need to add nitrogen to hydromulch to compensate for carbon:nitrogen ratio of mulch chosen Always put some seed in mulch Hydroseeding and hydromulching together should be reserved for special cases when moisture is sufficient to keep the seed moist for 2 to 3 weeks after seeding
Fabic or mats: jute, excelsior, woven, paper, plastics, nets	Especially useful on steep slopes Nets good in high wind areas	Expensive: 4 to 5 times more than tacked straw High labor input for anchoring Not effective on rough surfaces or rocky areas Erosion from beneath may be a problem	Used only on limited critical areas because of cost
Manure and sewage sludge	Can protect soil surface and adds nutrients, such as nitrogen, phosphorous, potassium, sulfur	When used alone, it becomes wet, then dry; can lose much of nitrogen through volatilization of ammonia	Needs 5, 10, 15 tons/acre in order to protect soil On bentonite spoils, a grass establishment study showed that an application of wood chips as mulch and sewage sludge as nitrogen supplier was more effective than a high application (400 parts per million) of inorganic nitrogen

Table 14 (Cont'd)

Type of Mulch	Advantages	Disadvantages	Comments
Asphalt	Rapid-curing asphalt keeps straw and other materials in place Slow-curing asphalt allows for growth of seedlings before it cures Coats surface, remains intact 4 to 10 weeks A stabilizer for straw Nonporous and conserves water underneath it Some plants react positively to it	Nonporous; thus causes surface water to run off Some plants react negatively to it	Make decision based on type of asphalt (slow, medium, rapid curing) desired Make decision based on reaction to asphalt by plant species desired 12,000 gal/acre an average application Typically heated and spread by spraying Apply from top of slope down, so impermeable caps are built on clods of soil down the slope, leaving sides free for seedlings to come out of and to absorb water
Resin emulsion in water	More porous than asphalt Insoluble in water Resistant to weathering		600 gal/acre good against wind erosion Often considered superior to asphalt
Latex emulsion	Resistant to erosion	Limits water penetration Some studies indicate it is less effective than some other mulches	

control, reintroduction of micro-organisms, and weed control around shrubs and within row plantings.

Mulch provides water erosion control by providing a protective surface between the soil and precipitation. This surface dissipates the kinetic energy of the raindrops, so that the soil suffers less structural destruction. Mulches also reduce splash erosion and surface sealing. They will slow the movement of water after a rainfall; allowing more time for infiltration. They also reduce both rill and channel erosion. Mulches are particularly important in the southwest for protecting newly seeded areas during short-term, high-intensity storms.

Mulches protect soils from wind erosion by covering the aggregate. They decrease wind velocity at the soil surface; soil particles that do move within the mulch will not move as far. Also, less soil is lost because of the increased soil moisture that mulches provide.

Mulches increase soil moisture by increasing infiltration, decreasing runoff, and reducing evaporation. (Evaporation is reduced because mulches restrict air movement.) The decreased evaporation rate increases the relative humidity at the soil surface.

Mulches also have an appreciable effect on soil temperature. A mulch darker than the soil it covers will raise the soil temperature. Conversely, a mulch lighter than the soil it covers will decrease the soil temperature. Mulches will also decrease the temperature variation within a soil because it causes it to retain more water.

Generally, the land manager will use all of the properties provided by mulching to develop a suitable micro-habitat for the germination and development of vegetative cover. Mulches are generally not used after plants have become established, but rather to provide the seed with the proper moisture, humidity, and temperature. The mulch will often protect seeds and seedlings from being eaten and allow soils to be reinoculated with micro-organism. In some cases, this may be more important than the mulch's water retention capabilities.

Mulches are not a panacea for all seed germination problems. In fact, they can cause problems by immobilizing nutrients, increasing soil toxicity, causing premature germination, introducing weed seeds, and attracting undesirable organisms.

Mulches can immobilize nitrogen, phosphorous, and sulfur. For example, when the carbon-to-nitrogen ratio (C:N) exceeds 25:1, net nitrogen immobilization can result from microbial action; however, these effects are temporary. The addition of a mulch high in organic matter such as straw or wood is often the cause. This also applies to immobilization of phosphorous and sulfur.

Some mulches may be toxic to certain plants. For example, mulches which are high in nitrogen may produce toxic concentration of ammonia.

Sometimes, application of a dark-colored mulch has caused premature germination because it increases the soil temperature. Since germination occurs before the spring rains, the seedlings die due to lack of soil moisture.

Mulches can also introduce undesirable organisms into an area. Weed seeds may occur in mulches such as hay, straw, or native grasses. Certain mulches will attract undesirable organisms. For example, excelsior will attract mice who will eat the seed.

Certain major operational problems with mulches have been noted. Low-density mulches which have not been tacked down tend to float downhill with runoff. If moving water gets under fabric or other mats which have not been properly tacked down, erosion will occur under the mat. In other cases, mulching treatments have been covered by erosion from areas adjacent to them; once covered, they may become totally ineffective.

When considering use of a mulch, several factors must be examined. These include color, density, roughness, durability, tenacity, availability, toxicity, decomposition rate, manner of application, and cost. These factors must be considered in terms of the current site conditions, the projected revegetation species, and the ultimate site use.

Four basic procedures are used to apply mulches:

1. Mulches such as straw, hay crop residues, and manure can be spread by wagon and tacked down.

2. Mulches such as crop residues, which are plowed under, can be grown in place.

3. Mulches applied as a liquid, such as sewage sludge, asphalt, wood residue, sawdust, woodchips, or bark, can be mixed with seed or fertilizer. They may be applied from a truck or hydromulched (sprayed).

4. Some may be spread as a solid sheet of paper or plastic. Nets are applied by hand.

Irrigation

Several factors must be considered when deciding whether to irrigate. The most important factors are rainfall amount, intensity, and timing. If an area receives fewer than 10 in. (250 mm) of precipitation per year, irrigation will probably be needed. In determining the amount of irrigation required, both the plant's water needs and the soil type must be considered. Soils that are high in clay, have low organic matter, and are compacted will have a low infiltration rate; however, a clay soil will retain more water than a sandy soil.

Irrigation has two basic purposes: (1) leaching salts or toxins out of the soil and (2) supplying supplemental water for establishing vegetation. The two basic techniques for supplying the water are water harvesting and irrigation.

Water harvesting is done by manipulating the soil's surface configuration. This is usually done by techniques such as pitting or gouging; the size of the impressions left can be checked by looking for pools or gullies. If pools or gullies develop, the water collection area is too large. In some

cases, a chemical sealant may have to be added to increase runoff into the plant growing zone. Generally, high clay soils will not require a sealant. On sandier soils, a sealant may be needed. This technique has increased plant production by up to 25 percent.

Placement of snow fences is another water-harvesting technique. Up to 90 cu ft (3 m^3) of water for each linear foot of a 4-ft (1.2-m) fence can be harvested. Twelve-ft (3.6-m) fences have collected up to 1100 cu ft (31 m^3) of water per linear foot. Controlling snow melt with fences can produce surface cracking which will facilitate seeding. Fences also collect mulch and windblown seeds.

The drip and the sprinkler irrigation systems are most commonly used to rehabilitate land in arid regions (see Table 15). Drip systems, which apply moisture directly to the plant, usually consist of a pipe with emitters placed at intervals. The emitters vary from nozzle-like devices to simple holes in the tube. The water is then placed directly on the soil within the plant's root zone.

Sprinkler systems irrigate large areas rather than individual plants or clumps of plants. The moisture is sprayed over a large area.

Generally, the drip system is the most water-efficient, but the most costly. It moves moisture to the outer edges of the root zone and can be used to apply fertilizer. It eliminates leaf burn and fruit spotting caused by salt accumulations on the plants. However, the emitters tend to get clogged by sediment, algae growth, or chemical precipitates. It is more susceptible to rodent damage and to breakage when temperature causes the joints to expand and contract. Salt buildup has also been reported near the emitters on the soil surface.

Sprinkler systems have the disadvantage of requiring larger amounts of water. They are less expensive because they last longer and are less labor-intensive. They are also more portable.

Irrigation can be costly; however, the more arid the region, the more likely that the lack of adequate soil moisture will be the limiting factor. The cost can be kept to a minimum by watering only during the most critical times. For example, the most critical time for a grass is during early growth and root development. Woody species develop drought resistance in midsummer or later, and older plants of all classes are better able to resist adverse conditions than seedlings. For arid areas, it is recommended that the amount of precipitation occurring at the most favorable year for a plant to develop be replicated. Deep rooting and lateral extension of roots should also be encouraged.

Whenever irrigation is used, salinity management will be a concern. The land manager must maintain the land's productivity as well as prevent the water supply from deteriorating. Traditional management requires treating the soil with an amount of water which exceeds the evapo-transpiration rate. However, plants can tolerate some salts in their root zone; therefore, less water can be applied.

Table 15

Advantages and Disadvantages of Drip and Sprinkler Irrigation Systems
(From User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining [SEAM] Program, General Technical Report INT-64, [USDA, Forest Service, 1979], p26.)

Type of Irrigation System	Advantages	Disadvantages	Comments
Drip irrigation	Uses one-third less water	If water contains high sediment level, it will clog the lines, unless well filtered	Also called trickle irrigation Plant densities will be less; this can be a disadvantage, but not always
	Evaporation is minimal	If water is high in salt, salt deposits can build up around the emitter openings	Adequate filtering system crucial
	Amounts of water can be placed directly where wanted	Needs more maintenance than a sprinkler to check filtering system	Quality of water (sediment, salinity) a factor
	Especially useful on steep slopes, under power lines (because it is safer), between buildings, on critical areas	Labor-intensive Less easy to move Shorter life span than sprinkler system	Three types of emitters: spitter (puts out a spray); single (puts small amount in local place); and bi-wall (plastic tubing with pin-prick opening to emit water)
	Moves salts away from plant roots Well-suited for woody plants	Higher costs than sprinkler	A portable drip system, using a 500-gal tank has been developed by the USFS Rocky Mountain Experiment Station at Albuquerque
Sprinkler irrigation	Less filtering needed	More evaporation will occur	Choose between solid set or movable
	Less expensive than drip	Need larger water supply	High plant densities possible
	Less labor-intensive	Frequency of application higher than drip	
	Longer life		
	Easier to move, more flexible		

4 MAINTENANCE TECHNIQUES FOR TRAIL AREAS

The trail maintenance techniques discussed in this chapter are based on applications used for Off-Road Recreational Vehicle (ORRV) trail areas.

Managing a trail area requires mitigating the environmental problems which ORRVs cause. Locations should be chosen to establish environmental sampling plots. The manager must determine how often they will be read and evaluated. The information obtained from these evaluations will allow the manager to develop criteria for determining permissible impacts.

Through trial and error, the State of Washington has learned to design ORRV trails that will be less susceptible to environmental damage, especially soil erosion.[53] The state's Department of Natural Resources has decreased vehicle impact by changing trail grades, building culverts, and using various other methods. The Department's personnel bypass the most vulnerable soil types or, if necessary, surface soft spots with crushed rock. Sometimes a trail has to be closed on a seasonal basis. For instance, a trail on a clay soil with a steep grade is closed during the spring thaw.[54]

It has been proposed by the Environment and Public Policy Committee of the Geological Society of America that:

> Some ORV areas, depending on their nature and size, could be divided into parcels for sequential use and reclamation, thus providing the least inconvenience to the ORV users. The use and reclamation of successive land units could allow reclamation plans to be modified as experience is gained. This practice also could insure that the success of reclamation efforts is evaluated before use of another land parcel is permitted.[55]

One way of controlling erosion and preventing large gullies on ORRV trails is to install water bars or regrade road sections. The State of California had to take immediate action when steep hillside areas in Hollister Hills Park were eroded almost beyond control. The California Department of Parks and Recreation has noted that creating an embankment perpendicular to the face of the hill kept it from being used by ORRVs. Then brush has a chance to take hold and make further use less attractive. These measures have been successful in maintaining managed hillclimb areas and in rehabilitating several overused slopes.[56]

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[53] David Sheridan, Off-Road Vehicles on Public Land (President's Council on Environmental Quality, 1979), p 50.

[54] Off-Road Vehicles on Public Land, p 50.

[55] Impacts of Off-Road Vehicles, The Geological Society of America, Committee on Environment and Public Policy, Boulder, CO (May 1977), p 8.

[56] Robert Rasor, Five State Approaches to Trailbike Recreation Facilities and Their Management (American Motorcyclist Association, 1977), p 17.

The State of Washington's Department of Natural Resources has been experimenting with several erosion control methods. They have implanted concrete blocks and chain link fences in the trail surface to stabilize the soil and to prevent vehicle wheels from breaking up the surface material. This also improves traction, which is a benefit to the trailrider.[57]

The Pacific Northwest Region of the U.S. Forest Service is developing a guide which provides information on maintaining recreational trails for ORRV use. It suggests that forest development trails be assigned to one of three maintenance levels (see Table 16). Level I maintenance refers to protection work that will "keep damage to the adjacent land resources to a minimum and provide for user safety."[58] These activities include maintenance of water bars, culverts, and ditches; drainage at bog holes; opening creek channels at a trail crossing; removal of log jams at bridges; replacement of temporary drain dips with water bars or culverts; and blocking parts of duplicate trails. These techniques are used mainly to facilitate drainage in the trail system.

Level II maintenance refers to activities performed on long-term primitive trails. "Trails in this level are maintained at sufficient cycles to protect the investment and to prevent deferred work from adding to the backlog of other needed reconstruction."[59] At this level, drainage and tread repair work is performed in addition to Level I maintenance. When enough work has accumulated, slide removal and tread work are done to decrease the "move-in" costs of maintenance crews. Logging out and brushing are programmed for when they will be most feasible economically. When trails in this level have not been maintained recently, traffic restrictions are then imposed to decrease or restrict traffic from damaged areas.

Level III maintenance is done on long-term basic trunk and special recreation trails where specific levels and types of traffic are encouraged. This level requires more frequent and complete maintenance due to heavier and long-term use. Brushing and logging out of trails is done more frequently. More attention is focused on tread smoothness and on root and rock removal.

Restoration maintenance or minor reconstruction are the types of work that will immediately reduce operating problems or maintenance expenses. These activities are not the same as the recurrent maintenance of levels I, II, and III, but should be planned as a part of the annual maintenance programming.[60]

Restoration consists of returning the trail to its original constructed standard. This can be done by replacing bridge deck and railing, replacing

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[57] Five State Approaches to Trailbike Recreation, p 31.

[58] Personal communication between Roland Emetaz (USDA, Forest Service) and R. Goettel (CERL), 1980.

[59] Personal communication between Roland Emetaz (USDA, Forest Service) and R. Goettel (CERL), 1980.

[60] Personal communication between Roland Emetaz (USDA, Forest Service) and R. Goettel (CERL), 1980.

Table 16

Summary of Trail Maintenance Requirements
(From User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining [SEAM] Program, General Technical Report INT-64, [USDA, Forest Service, 1979], p 26.)

Premises → Kept Safe for Permitted Use and Maintained by the Most Economical Methods

Objectives → Protection of Resources: Soil, Water, Vegetation + Preserve Investment, Preserve Rec. Exp. Levels + Sustain Constr. Quality; Be Convenient, Pleasant, Aesthetic

Work Items:	Maintenance Level I	Maintenance Level II	Maintenance Level III
-- Drainage Crossings (Bridges, Footlogs, Ford)	Periodically, maintain only for free flow of water.	Periodically, maintain to sustain constructed quality of crossings.	Currently, maintain for convenience of use and pleasing aesthetics at site.
-- Brush Encroachment	Occasionally, remove brush only when tread is encroached upon.	Occasionally, remove brush to maintain clearing area specified for Construction in original Constr. Specs.	Periodically, remove brush encroaching on trailway area.
-- Timber Down on Trailway	Occasionally, remove down timber, only as necessary to make trail passable and to prevent walk-around trails.	Periodically, remove all logs & windfalls that extend across tread area. Occasionally, remove all down material from within the clearing limits.	Currently, remove all down logs, windfalls, loose stumps, and limbs from within the clearing limits.
-- Tread and Tread Drainage	Occasionally, remove all loose rocks 6 in. and larger and drain tread where washing is evident.	Periodically, clean the tread of all loose rocks 4 in. and larger. Occasionally, reshape tread to Standard Constr. Specs.	Currently, clean tread of all loose rocks 3 in. and larger. Clean all drain facilities. Occasionally, remove protruding rocks and roots.
-- Slides, Slumps, and Rockfalls	Occasionally, clean out if passage is unsafe or if soil erosion damage is likely to occur.	Currently, remove if obstructing or hazardous to traffic. Periodically, if safe for traffic during the interim.	Currently, remove and repair any damage adverse to the trailside aesthetics.
-- Structures (Signs, Shelters, Cairns Railings, and Stiles)	Currently, maintain signs and bulletin boards for posting permitted use and restrictions to public.	Periodically, maintain all structures to facilitate proper use and to assist the Resource Mgr.	Currently, maintain all structures to original Constructed Specifications; signing to be in accord with the Regional Sign Policy.

PRIMITIVE ← → MODERN

Maintenance Frequency:
Currently = Annual, at least once each year.
Periodically = 1 time in each 2-year period.
Occasionally = 1 to 2 times in each 5-year period.

the log or rock retaining wall, removing slide material, or replacing logs in the corduroy section (where logs are laid together transversely).[61]

Minor reconstruction includes "all work on the existing trail which will either improve that section to existing or planned standards or relocate that section to eliminate resource damage or improve safety and/or convenience. This includes eliminating bog holes, reconstructing bad switchbacks, surfacing portions of tread, relocating out of meadows and inactivating existing tread, and relocation to better the crossing of intermittent streams."[62]

[61]Personal communication between Roland Emetaz (USDA, Forest Service) and R. Goettel (CERL), 1980.

[62]Personal communication between Roland Emetaz (USDA, Forest Service) and R. Goettel (CERL), 1980.

5 INSTALLATION PROGRAMS

The Army has many installations located in arid and semi-arid ecoregions. This chapter discusses how the major installations in these regions are maintaining their training lands (Figure 2). The installations investigated are Forts Carson, Sill, Bliss, Hunter Liggett, Huachuca, Sam Houston, Irwin, Hood, Riley, and Yakima Firing Center. This information was obtained from installation land management documents and from conversations with installation environmental and land management personnel.

Fort Bliss

Fort Bliss is studying the extent of wind erosion at the installation; an evaluation is expected in 2 years. Fort Bliss has also contracted for an ecological study to determine the effects of training on the post's land. Control areas (areas left fallow) and treatment sites at areas where training is still conducted have been established. The study will obtain information

Problems	Bliss	Carson	Hood	Hunter Ligett	Huachuca	Irwin	Riley	Sill	Sam Houston	Yakima
Erosion	x	x	x					x	x	x
Compaction						x		x		
Direct Vegetative Loss				x		x		x		
Fire				x	x					
Encroachment			x	x	x	x	x			
Maintenance Activities										
Studies	x	x		x				x		
Planting			x	x	x		x	x	x	x
Contour					x					
Rotation		x							x	
Structural Erosion Control		x							x	
Funding — Leases							x		x	
Funding — In-House	x	x	x		x			x	x	

Figure 2. Installation problems and maintenance activities.

about the effects of training on soil properties and vegetative characteristics (e.g., soil compaction, available plant moisture, and seedling vigor). There is currently no significant range revegetation being done at Fort Bliss.

Fort Carson

Fort Carson is conducting a major effort in training area management. First, range site maps were prepared. Using these maps and site investigations, they were able to determine each site's vegetative and structural requirements. Installation personnel prepared range site, vegetation, and soil maps. The Soil Conservation Service then prepared a conservation plan for the area. Similar maps will be developed when the post acquires Pinyon Canyon for training purposes.

Seeding has been done with a range drill, using native grasses with an overseeding of crested wheat as a nurse crop. If the range contains less than 30 percent vegetative cover, a pit and seed technique is used. If the coverage is 30 to 60 percent (considered excellent), only pitting is used. The primary problem has been with weather and grasshoppers; an attempt to overseed with grains failed when grasshoppers ate the grain.

Structural erosion control has included dam construction, diversion, and gully blocks. Only a little terracing and bank sloping has been done. This is because once a tank breeches any level of the terrace, the whole terrace collapses. Bank sloping has been difficult because of problems in reestablishing vegetation.

Fort Carson has established plant material test plots to test seed sources. Long-range studies have been started to determine the long-term trends of the training area maintenance program. The test plots have been established in two different ecotypes. Four basic treatments are being examined for each ecotype: (1) pitting and seeding with a native mixture, (2) pitting and seeding using an introduced mixture, (3) pitting, seeding, fertilizing, mulching, and seeding with a native mixture, and (4) pitting, seeding, fertilizing, mulching, and seeding with an introduced mixture. The success of the treatment will be judged on the change in percent cover. Sampling will be done using low-level aerial photography. A classical range trend study will not be conducted because the required sampling is too expensive. Of particular interest are the results of the revegetation efforts in comparison to their costs.

Personnel from the Waterways Experiment Station, Vicksburg, MS, have conducted studies at Fort Carson to determine the percentage of vegetation destroyed by the pass of one tank; however, the evaluators are not certain of the accuracy of the study results.

Currently, Fort Carson does not rotate training areas; however, rotation of some areas is planned when the installation is expanded.

Fort Hood

Until 2 years ago, the only land maintenance done at Fort Hood was building watering points in conjunction with grazing leases. There was also some brush control for cedar through propagation contracts; the Land Management Branch used a bulldozer to provide brush control, some reshaping, and disking and scarifying for reseeding.

Attempts to re-establish vegetation have been unsuccessful, because the areas get too much traffic too soon after seeding. Range regulations which require tracked vehicles to stay on the trails and which require areas excavated for tank traps, foxholes, etc., to be backfilled cannot be enforced.

The most successful project has been putting in "farm ponds" to act as settling basins. Some revegetation has been successful where they cut cedar and left the slash for protection after reseeding. There has been controlled brush burning for the past 2 years (4600 acres [861.59 ha] were burned during 1982). The current SCS estimate for soil loss due to erosion on the training area at Fort Hood is 0.01 to 50 tons/acre/year.

Fort Huachuca

The U.S. Army Communications School (tenant activity) requires large clear areas for training at Fort Huachuca. Recently, 950 acres were cleared for this purpose, using two techniques. The first involved leveling (grading) and then reseeding the area, and then maintaining it by mowing. A second method used was root plowing the vegetation, then burning and reseeding the area. This second technique has been very successful in some areas. For example, perimeters of sensitive test sites have been converted to pasture land using native grasses.

One major problem at the installation is encroachment of juniper. This has been successfully controlled by allowing people to cut junipers for Christmas trees and then burning to control the junipers' coppicing tendency.

The east range at Fort Huachuca is a specific example of the type of conditions existing there. When the Army obtained the east range, it was denuded grassland; the topsoil had been washed away, and mesquite and creosote bush had taken over. Installation personnel are now using a contour system on the range. To revegetate, they scalp-plow for root infiltration; however, no fertilizer or irrigation is used due to its high cost. Precipitation is the most restrictive factor for seeding, since the range does well in average-to-wet years, but poorly in dry years.

Love grass was planted in the 1950s; but since it is a weed, it will not be planted again. The most successful plantings have been blue panicum grass. Other types planted were panicum, side oat, and bristle grass. In 1982, four-wing saltbrush was planted, but it is too early to determine results.

Two different broadcasting techniques are used for planting: hand broadcasting or using a D-8 dozer which pulls a broadcaster. Two rippers (one attached to each side) are also pulled behind the bulldozer. Revegetating

watersheds usually begins with work on the upper end and gradually works down. It takes about 4 years to finish revegetating each watershed.

Fort Hunter Liggett

Hunter Liggett's major problem is invasion of star thistle. Control of the star thistle by herbicide has been tried, but with little success.

The soil at Hunter Liggett is relatively stable and slow to erode. Areas with trails to be eliminated are treated by disking; vegetation will then return naturally after a short time. Treatment for heavily used, completely denuded areas consists of disking and reseeding. Reseeding is usually done in areas where erosion has occurred (e.g., near construction areas and landing strips or where a different species is desired for grazing). Fertilization is used only around construction sites.

The installation's training areas are used continuously from May until October or November. This creates a lot of dust and loss of vegetation, but there is a limited amount of sheet erosion. Autumn rains speed up the erosion, but the amount of soil loss is not at a critical level. Hunter Liggett is now working with the SCS to determine sheet erosion rates.

There has been good coordination and cooperation among the military (7th Infantry and Combat Experimental Command) and the Natural Resource Office in determining where troops can practice ground-disturbing activities such as road building and digging foxholes. Installation management hopes this coordination can be maintained and improved. Each unit is required to restore the area after it has finished training. Money for the restoration is included in the operating funds used for unit training.

Fort Irwin

There is no rotation of training areas at Fort Irwin, because the recovery rate of vegetation is too slow. The major problem is compaction of the soil, which prevents most plants from becoming established, since their root systems cannot penetrate the soil deeply enough to reach moisture. The compaction also increases the intensity of the flash flooding that normally occurs in the Fort Irwin area.

No large-scale range reseeding program is recommended for the installation. According to the fish and wildlife plan, it is desirable to introduce four-wing saltbush, mesquite, willow, and Russian olive around springs where existing vegetation is not satisfactory and in areas where enough water is available from artificial devices which provide water for wildlife.

Fort Sam Houston

Fort Sam Houston rotates training areas, but the rotation is subjective because they have no means of measuring when it is time to rotate. At Camp Bullis, most of the training is conducted on 28,000 acres. The training is a

mixture of infantry and armor; 1200 acres at the main post receive minimal use, mainly medivac training.

Normally, brown top mellet, corn, side oats gramma, and fescue are used when planting is done. KR (King Ranch) bluestem is also planted, using 99 percent live (viable) seed; however, this increases the expense. Grass is seeded mostly in the fire lanes. A cyclone broadcast spreader attached to a tractor is used for all seeding. Mulches and fertilizers are not used. Structural erosion control measures include gully plugs and check dams.

Fort Sill

The major problems at Fort Sill is maintaining a tree line, in which artillery may hide and fire. The smaller trees are run over by vehicles, vegetative cover between the larger trees is lost, and the root zones become compacted. The larger trees then die because of lack of moisture caused by the compaction.

A plan has been developed to plant a screen of black locusts and perhaps osage orange to block areas that are to be protected, such as the travel trails of animals. Hardwoods would then be planted behind the screen, to maintain the integrity of the existing hardwood bottoms. Thus, the smaller trees will replace the older ones that are dying.

Johnson grass (a noxious weed) is another problem. There has been no attempt to plant large areas in native grasses. Test plots have been established to determine the amount of effort needed for the revegetation program to have the desired results. Particular items that will be examined are cost, rapid results, and trade-offs.

On some of the ranges, bermuda and rye are being planted for immediate stabilization; native grasses will then be allowed to invade the area. The overall vegetation program is scheduled for 1983.

Yakima Firing Center

At the Firing Center there is an erosion control seeding program involving about 1000 acres (404.69 ha) per year funded through grazing leases. They are reseeding with crested wheatgrass (with no irrigation); planting is being done with a rangeland drill pulled by an articulated rubber tire skidder. This program has had only limited success because the troops use the area again too soon after planting. Also, there is no rotation of training areas, since they are used every year from March to July and from September to December.

Fort Riley

Fort Riley has established a hay lease program and is trying to restore native prairie grasses on the leased areas. As funds become available, the program will convert turf grass on some of the ranges to buffalo grass. Currently, disking and drilling are used to replant; however, the extension

range specialist at Kansas State University has also noted that seed should be sown under a stubble cover crop.

The Facility Engineer's mowing requirements are being augmented through the lease program. The leases are designed so that the leaseholders do the aesthetic and production mowing. The lessees are responsible for controlling noxious weeds within their leaseholds. Noxious weeds present include musk thistle, field bindwood, and Johnson grass. The leaseholders also control invading woody species, such as buckbrush, eastern red cedar, thorny honey locust, Siberian elm, and wild sumac.

Lands near the cantonment area, which receive little or no management, are being encroached upon by volunteer trees, shrubs, and brush. Lessees are allowed to claim (mow) what they can. This type of management is intended to bring the area up to full production so it can be included fully in the lease program. Although these lands can be used for training, they are not used very frequently.

6 CHECKLIST OF REHABILITATION TECHNIQUES ON ARMY INSTALLATIONS

The Army conducts some training maintenance activities on all its installations. This work varies from no activity to complete pitting and reseeding of selected areas. The land managers already have the background data necessary to start several maintenance activities. These data include the climatic factors, soil types, and vegetative conditions. However, other information which might be useful to the land managers is not immediately available. For example, many of them do not know precisely what the effects of a particular training mission will be on their installation. Every installation has unique problems due to geographical differences; this causes the soil makeup and vegetation to vary greatly. Currently, a number of installations are conducting tests to try to determine the effects of different training activities; however, this research has not yet been systematically organized.

Fort Carson probably has the most active training area maintenance program. Its program is very well run and is coordinated with the SCS. This type of cooperation with other Federal agencies can provide installations with expertise for carrying out rehabilitation projects. In particular, SCS and Service's SEAM programs has some information which is applicable to military installations.

One major problem on most military installations is the lack of coordination between the training officer and the lands management branch. Although their goals often appear to conflict, in the long run they are actually quite compatible. The training officer is concerned with getting troops trained and prepared to enter the field. The land manager is concerned with providing the training officer with an environment where he/she can continue to train troops, not just now but years in the future. The problem arises because the training officers do not appear to understand the land's capabilities; conversely, the maintenance officers lack knowledge about the pressure faced by training officers. The lands manager must know precisely how the military mission will affect a certain piece of land as well as what can be done to decrease those effects.

Several techniques can potentially be used to handle land rehabilitation problems, and it is suggested that a number of different techniques be tried. There should always be close cooperation with the SCS and the U.S. Forest Service on this type of project. These agencies have developed expertise in this area because of their work in reclaiming disturbed sites. However, caution must be exercised because reclaiming strip mines and maintaining training areas are not the same thing.

It would be worthwhile for the military to investigate the use of aerial seeding and irrigation. Although aerial seeding tends to be inefficient, it would still reduce the cost of seeding. If seeding costs are negligible, the inefficiencies can be made up quickly. Aerial seeding using military aircraft needs further investigation.

Irrigation has generally been ignored on most military installations because of its cost; however, use of irrigation to establish seeds could pay for itself in several ways. For example, it would save the cost of replanting

seeds that do not germinate because of lack of moisture; also, the level of training on the land could be increased greatly because vegetation would grow back more quickly. Despite these benefits, however, irrigation should not be considered a long-term solution; instead, it should only be used to establish the vegetation.

Table 17 is a generic checklist for the lands manager to use when deciding on techniques to rehabilitate an area. The list covers the basic categories of available rehabilitation techniques: presite planning, site preparation, fertilization/pH control, species selection, planting, mulching, irrigation, and monitoring. Use of this list will insure that each area is considered. It will also allow the local agronomist or range management expert to successfully complete a rehabilitation program. Not all sections of the checklist will be used for every project.

Presite planning covers three basic areas: baseline information, site specifications, and rehabilitation programs. The manager should first insure that the baseline information needed to begin the project and to make the ultimate biological decisions is available. Site specification deals with the conflicting goals in which an area may become involved. These include, primarily, military training and, secondarily, uses such as grazing outleases, agricultural outleases, rare and endangered species, fish and wildlife management, and recreation. Listed under Rehabilitation Program are the areas or steps in such a program (e.g., removal of unwanted vegetation, species selection and planting, removal of irrigation equipment). The project site requirements and site conditions will determine whether these steps need to be taken. The land managers must decide what needs to be done. For instance, the area may require primary tillage due to a compacted clay layer, and it may require fertilization, species selection and planting, and mulching. After the users decide which operations are to be performed, they then proceed to the section of the checklist dealing with that operation.

The rest of the checklist reminds the user of considerations regarding the site specifications and project goals (e.g., removal of vegetation). It also provides a list of considerations that will help the manager organize the work. For example, for vegetation removal, will the user employ chemicals, fire, or mechanical devices for removal? Is the equipment available? Is manpower available? What would be the cost of doing this? Is it best to do this job in-house or out-of-house?

Some techniques which are standard practice in range management and general agricultural management are used very little or not at all on military installations. Rotation is a primary example of such a technique. Both range and agricultural managers consider it good practice to let an area "rest" for awhile (i.e., let the area lay fallow or unused). However, military constraints generally will not allow for an area to sit idle for 2 or 3 years. It may be possible, though, to rotate an area in a slightly different manner. With this practice, less destructive training activities would be performed at the beginning of the rotation; later, at each subsequent point in the rotation, more and more destructive techniques could be used. The rehabilitation program would begin again after the most destructive use, such as heavy use of tracked vehicles. Generally, the expertise is available on military installations to attempt this rotation method.

Table 17

Rehabilitation Checklist

1. PRESITE PLANNING

Baseline Information

- Topography
- Soils
- Climate
- Vegetation

Site Specification

- Military Training
- Grazing Outleases
- Agricultural Outleases
- Forestry
- Rare and Endangered Species
- Fish and Wildlife Management
- Recreation

Rehabilitation Program

- Removal of Unwanted Vegetation
- Primary Tillage and/or Grazing
- Secondary Tillage
- Fertilization/pH Control
- Species Selection and Planting
- Mulching
- Irrigation
- Removal of Irrigation Equipment
- Monitoring

2. SITE PREPARATION

Removal of Vegetation

- Chemical
- Fire
- Mechanical
- Equipment Available
- Manpower
- Cost
- In-House
- Contract

Primary Tillage and/or Grazing

- Technique Chosen
- Equipment Available
- Manpower
- Cost
- In-House
- Contract

Secondary Tillage

- Technique Chosen
- Equipment Available
- Manpower
- Cost
- In-House
- Contract

3. FERTILIZATION/pH CONTROL

- Technique Chosen
- Equipment Available
- Manpower
- Cost
- In-House
- Contract
- Material Available
- Cost

4. SPECIES SELECTION

5. PLANTING

Plant Material/Planting Techniques

- Availability
- Cost

Planting Equipment

- Manpower
- Availability
- Cost
- In-House
- Contract

Table 17 (Cont'd)

6. MULCHING

Technique Chosen
Material Available
    Cost
Equipment Available
    Manpower
    Cost
In-House
Contract

7. IRRIGATION AND REMOVAL OF IRRIGATION EQUIPMENT

Irrigation

Technique Chosen
Equipment Available
Manpower
Source of Water
Cost
In-House
Contract

Removal of Equipment

Technique Chosen
Manpower
Cost
In-House
Contract

8. MONITORING

Technique
Equipment
Manpower
Cost
In-House
Contract

7 CONCLUSIONS AND RECOMMENDATIONS

Information on land rehabilitation techniques was compiled from the literature and from discussions with land managers at selected Army installations in the southwest. The following conclusions are based on this information and are the basis of a preliminary structure which the land manager can use to develop techniques to maintain training areas. Rehabilitation operations can be broken down into seven major phases: (1) presite planning, (2) site preparation, (3) fertilization/pH control, (4) species selection, (5) planting, (6) mulching, and (7) irrigation.

The order of operations and the extent to which each activity is carried out depends on site condition and installation goals. However, the land manager can use these steps as the basis for developing a viable land maintenance and rehabilitation program.

Coordination of activities with other Federal agencies, such as the Soil Conservation Service, can provide installations with information and expertise that will be helpful in carrying out individual rehabilitation programs.

An important factor in developing a rehabilitation program is coordination between the lands manager and the training officer. Cooperation between these two offices will reduce problems in implementing the program and will help produce compatible, long-range rehabilitation and maintenance activities.

Before starting a rehabilitation project, the lands manager should first establish certain baseline information about the installation. This will insure that decisions made during project implementation will be appropriate to the installation's needs.

It is recommended that the checklist provided in Table 17 be used as a basis for establishing and carrying out a land rehabilitation program at Army installations.

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APPENDIX A:

POINTS OF CONTACT

This appendix provides a list of contacts who can supply information on plant materials, species, and equipment for use in revegetation activities.

The SCS-sponsored Plant Material Centers develop new plant strains and improve existing varieties. Some centers specialize in growing and developing native species. The knowledge gained through their research is available to landowners and commercial producers who want to produce a large volume of certified seed for the market.

The Plant Material Centers have three levels. At the first level are the managers and soil conservationists. These people do the actual development of and experimentation with the different strains and varieties of plants.

After a new strain or variety is developed, it must be tested. The field plant materials specialists -- the second level in the organization -- test the new plant in the field. They then coordinate with other disciplines associated with plant use, such as range conservationists, agronomists, biologists, and foresters. They also coordinate with the seed growers who want to produce new plants commercially. The field plant material specialist is also a liaison to other State and Federal agencies concerning the use of the new plant in other programs.

The Technical Service Centers (TSC) are the third level of the organization. These centers are similar to the regional offices of other agencies. They coordinate the activities of a designated group of states; i.e., they automatically coordinate the activities of a certain group of field specialists and centers. The TSCs also maintain contact with other Federal and State agencies within their designated groups of states.

Following is a list of specialists and managers at the three levels. Also included is the address of the National Plant Materials Specialist, who coordinates the three levels.

Soil Conservation Service
Plant Materials Specialist
as of
January 1982

<u>National Plant Materials Specialist</u>

Robert S. MacLauchlan
Soil Conservation Service
P.O. Box 2890
Washington, DC 20013
FTS: 447-5667

TSC Plant Materials Specialist

Northeast TSC
W. Curtis Sharp
1974 Sproul Road
Broomall, Pennsylvania 19008
FTS: 489-3222
Comm: (215) 461-3222

West TSC
Jack Carlson
Room 510
511 N.W. Broadway
Portland, Oregon 97209
FTS: 423-2841

South TSC
Arnold G. Davis
P.O. Box 6567
Fort Worth, TX 76115
FTS: 334-5282

Midwest TSC
Kenneth Blan
USDA-SCS
Federal Building
U.S. Courthouse, Room 378
Lincoln, Nebraska 68505
FTS: 541-5355

Field Plant Materials Specialist

Alaska
Calvin Miller
2221 E. Northern Lights Blvd.
Suite 129
Anchorage, AK 99504
FTS: 399-0150 (ask for
(907) 276-4246)

Arizona
Jacob C. Garrison
3008 Federal Building
231 N. First Avenue
Phoenix, AZ 85025
FTS: 261-6711, ext. 43
Comm: (602) 261-6711, ext. 43

California
Robert D. Slayback
2828 Chiles Road
P.O. Box 1019
Davis, CA 95616
Comm: (916) 758-2000, ext. 275

Colorado
Wendell Hassell
Box 17107
Denver, CO 80217
FTS: 327-5651
Comm: (303) 837-5651

Florida
Donald C. Smith
P.O. Box 1208
Gainesville, FL 32602
FTS: 946-7201, ext. 137

Georgia
Harry J. Haynsworth
P.O. Box 832
Athens, GA 30613
FTS: 250-2114 or 2115

Hawaii
Robert J. Joy
Box 74
Hoolehua, HI 96729
Comm: (808) 567-6378

Idaho
George James
304 N. 8th Street
Room 345
Boise, ID 83702
FTS: 554-1610
Comm: (208) 334-1610

Kansas
Jack Walstrom
P.O. Box 600
Salina, KS 67401
FTS: 752-4753

Kentucky
Donald S. Henry
333 Waller Avenue
Lexington, KY 40504
FTS: 355-2730

Michigan
Dorian A. Carroll
1405 South Harrison Road
East Lansing, MI 48823
FTS: 374-6677
Comm: (517) 337-6701, ext. 6677

Mississippi
James Wolfe
Suite 1321, Federal Building
100 West Capitol Street
Jackson, MS 39201
FTS: 490-5197
Comm: (601) 960-5197

Missouri
Richard Brown
555 Vandiver Road
Columbia, MO 65201
FTS: 276-5218

Montana
Larry Holzworth
P.O. Box 970
Bozeman, MT 59715
FTS: 585-4332
Comm: (406) 587-5271, ext. 4332

New Jersey
Frank Webb
1370 Hamilton Street
P.O. Box 219
Somerset, NJ 08873
FTS: 342-5341
Comm: (201) 246-1206

New Mexico
William W. Fuller
517 Gold Avenue, S.W.
P.O. Box 2007
Albuquerque, NM 87103
FTS: 474-3277

New York
Fred B. Gaffney
U.S. Courthouse and Federal Building
100 S. Clinton Street, Room 771
Syracuse, NY 13260
FTS: 950-5520
Comm: (315) 423-5520, ext. 33

North Carolina
Vacant
P.O. Box 27307
Raleigh, NC 27611
FTS: 672-4318

North Dakota
Erling T. Jacobson
Federal Building
P.O. Box 1458
Bismarck, ND 58501
FTS: 783-4425
Comm: (701) 255-411, ext. 425

Puerto Rico
Vacant
Federal Experiment Station
P.O. Box 1000
Mayaguez, Puerto Rico 00708
Comm: (809) 832-4202

Texas
Richard Heizer
W. R. Poage Federal Building
P.O. Box 648
Temple, TX 76501
FTS: 736-1294 or 1291

Washington
James R. Stroh
360 U.S. Courthouse
Spokane, WA 99201
FTS: 439-3722

John Oyler
Soil Conservationist
360 U.S. Courthouse
Spokane, WA 99201
FTS: 439-3722

West Virginia
Vacant
75 High Street
Morgantown, WV 26505
FTS: 923-7151

Plant Materials Centers Managers and Soil Conservationists

NPMC
Keith Salvo
National Plant Materials Center
Building 509, BARC - East
Beltsville, MD 20705
FTS: 344-2175

Soil Conservationists
Bob Glennon
Bill Fry

Alaska
Robert Parkerson
Alaska Plant Materials Center
Star Rt. B, Box 7440
Palmer, AK 99645
FTS: 399-0150 (ask for
(907) 745-4469)

Soil Conservationists
Stoney Wright

Arizona
Jim Briggs
Tucson Plant Materials Center
3241 Romero Road
Tuscon, AZ 85705
FTS: 762-6491
Comm: (602) 792-6491

Soil Conservationists
Vacant

California
Kenneth Croeni
Lockeford Plant Materials Center
P.O. Box 68
Lockeford, CA 95237
FTS: 556-9000 (ask for (209) 727-5319)

Soil Conservationists
Gary Young
Rai Clary - Caltrans Project

Colorado
Sam Stranathan
Environmental Plant Center
P.O. Box 448
Meeker, CO 81641
FTS: 327-0111 (ask for
(303) 878-5131)

Soil Conservationist
Gary Noller

Florida
Don Smith - Acting
Brooksville Plant Materials Center
6225 U.S. 41 North
Brooksville, FL 33512
FTS: 946-2011 (ask for
(904) 796-9600)

Soil Conservationist
Vacant

Georgia
John D. Powell
Americus Plant Materials Center
P.O. Box 688
Americus, GA 31709
Comm: (912) 924-2286

Soil Conservationist
Mike Owsley

Hawaii
Robert J. Joy
Hawaii Plant Materials Center
P.O. Box 236
Hoolehua, HI 96729
Comm: (808) 567-6378

Soil Conservationists
Larry Shinshiro
Lawrence Yamamoto

Idaho
Charles G. Howard, Jr.
Aberdeen Plant Materials Center
P.O. Box AA
Aberdeen, ID 83210
FTS: 554-1111 (ask for
(208) 397-4181)

Soil Conservationists
Gary Davis
Vern McMaster

Kansas
Bob Dayton
Manhattan Plant Materials Center
Rt. 2, Box 314
Manhattan, KS 66502
FTS: 752-4296

Soil Conservationist
Danny McDonald

Kentucky
Charles Gilbert
Quicksand Plant Materials Center
Quicksand, KY 41363
Comm: (606) 666-5069

Soil Conservationist
Vacant

Michigan
Ellis G. (Bill) Humphrey
Rose Lake Plant Materials Center
East Lansing, MI 48823
Comm: (517) 641-6300

Mississippi
B. B. Billingsley
Coffeeville Plant Materials Center
Route 3, Box 215A
Coffeeville, MS 38922
FTS: 490-4211 (ask for
(601) 675-2588)

Soil Conservationist
Joe Snider

Missouri
Jim Henry
Elsberry Plant Materials Center
P.O. Box 108
Elsberry, MO 63343
Comm: (314) 898-2012

Soil Conservationist
Steve Brookerhoff

Montana
John G. Scheetz
Bridger Plant Materials Center
Rt. 1, Box 119
Bridger, MT 59014
FTS: 585-5011 (ask for
(406) 662-3579)

Soil Conservationists
Mark E. Majerus
Vernon P. Sundberg

New Jersey
Cluster R. Belcher
Cape May Plant Materials Center
Rt. 1, Box 236A
Cape May Court House, NJ 08210
Comm: (609) 465-5901

Soil Conservationists
Don Hamer
Phillip Koch

New Mexico
Wendell Oaks
Los Lunas Plant Materials Center
1036 Miller Street, S.W.
Los Lunas, NM 87031
Comm: (505) 865-4684 or 4685

PMC Research Assistant
Joe Fraser

New York
Donald M. Cattrell
Big Flats Plant Materials Center
P.O. Box 295, Rt. 352
Big Flats, NY 14814
FTS: 882-2611 (ask for
(607) 562-8404)

Soil Conservationist
Martin van der Grinten

North Dakota
Russell J. Hass
Bismarck Plant Materials Center
Lincoln Oakes Nursery
P.O. Box 1458
Bismarck, ND 58501
FTS: 783-4011 (ask for
(701) 223-8536

Soil Conservationists
Dwight Tober
Dale Darris

Oregon
Jack Peterson
Corvallis Plant Materials Center
3240 N.W. Granger Avenue
Corvallis, OR 97330
FTS: 420-4812
Comm: (503) 757-4812

Soil Conservationist
Scott Lambert

Texas
David G. Lorenz
Knox City Plant Materials Center
Route 1, Box 155
Knox City, TX 79529
FTS: 729-4011 (ask for
(817) 658-3922)

Soil Conservationist
Jon B. Muncrief

South Texas PMC
Doug Ledbetter
South Texas Plant Materials Center
Caesar Kleberg Wildlife Research Institute
Texas A & I University
P.O. Box 218
Kingsville, TX 78363
Comm: (512) 595-2388

Washington
Clarence Kelley
Pullman Plant Materials Center
Room 257, Johnson Hall
Washington State University
Pullman, WA 99163
FTS: 439-0111 (ask for
(509) 332-2024 - Office or
" " -2035 - Farm)

Soil Conservationists
Wayne Crowder
Frances E. Northam

APPENDIX B:*

GUIDELINES FOR SEED COLLECTION, TREATMENT, AND STORAGE

The way seeds are collected varies, depending on the species. This appendix provides general suggestions for collecting and treating seeds.

Guidelines For Seed Collection

1. Collect seeds from an environment that resembles the site to be revegetated as much as possible.

2. Collect seeds at their optimum ripening time and within a period of time that will allow them to remain viable until planting. For example, some seeds can only be stored for 6 months, while others can be stored for several years.

3. Collect seeds before storms, not after. Ripened seeds will often be scattered by winds that precede storms.

4. Test the viability of seeds by cutting and examining a sample. Generally, seeds that are filled are viable.

5. Collect seeds from a number of plants of the same species to maintain genetic variability.

6. It is important to handle the seeds properly after they are collected. Use cloth bags rather than plastic bags to collect and store the seed. Unless otherwise recommended, keep the seeds cool and dry. Clean and process the seeds as soon as possible after collection.

7. Instruct collectors on the proper methods of seed collection.

Information on seed collection equipment is available from the USDA Forest Service, Missoula Equipment Development Center, Fort Missoula, MT 59801.

Cleaning and Drying Seeds

It is best to let commercial seed dealers clean and dry the seeds, because they can do it more economically. They also have the equipment needed to clean most seeds.

Seeds should be cleaned soon after collection to maintain their viability. Weeds, insects, and trashy material must be separated from the seeds. The seeds should then be dried to the proper moisture content.

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* The information in this appendix is adapted from User Guide to Vegetation, Mining and Reclamation in the West, Surface, Environment and Mining (SEAM) Program, General Technical Report INT-64 (USDA, Forest Service, 1979), pp 20-22.

Seeds can be dried by spreading them in a thin layer over tarps or plastic sheets and leaving them exposed to the sun for several days. They should be stirred each day. If seeds are collected in the fall, they can be dried in a cool, protected building.

Other Treatments

Some seeds may require chemical treatment if they will be stored for extended periods of time. Seed inoculation may also be required.

Most commercial seed growers will inoculate legume seeds with nitrogen-fixing microorganisms as part of a standard seed treatment. The land managers should check to see if this has been done. Native legumes may require a different kind of inoculation than those used for introduced species. Commercial seed growers should be able to advise the land managers about this. The cost of inoculation is minimal and the treatment highly beneficial.

Inoculants other than those commonly used by commercial processors, such as microorganisms, are also important to successfully establish certain species. These inoculants (e.g., endomycorrhizae) are not available commercially and must be supplied by the topsoil.

It is better to inoculate seeds just before planting them. If inoculated seeds are going to be stored, commercial growers or available literature should be consulted to determine how long they can be stored successfully.

Seed Storage

After the seeds are dried, cleaned, and had any other necessary treatment, they should be stored according to advice given by a seed expert or guidance in the literature. The information will be very specific because different species react differently to temperature and humidity. While specific rules should be followed, there are a few general guidelines on seed storage:

1. Keep freshly collected seeds dry and avoid exposing them to high temperatures.

2. Seeds that are dried properly can be stored in unheated buildings for several months with little effect on seed viability. Seeds can be kept for longer periods of time if they are stored in airtight containers at temperatures between 33° and 38°F. Storage in airtight glass or metal containers is preferable to storage in plastic bags.

3. Avoid high humidity and high temperatures. If bagged seed becomes wet, open it and let the seed air-dry thoroughly.

4. Protect all seeds from rodents.

5. Proper labeling of seeds is extremely important. Later, these records will help identify which species are best adapted to a site. Labels should contain the following information: (1) precise species name,

(2) seller's or collector's name, (3) date of collection, and (4) detailed information about the location of the seed source.

6. Maintain complete files on all seeds regarding: (1) all information on the seed container labels, (2) information on germination tests, purity, and pure live seed percentage, (3) characteristics of the site from which the seed was collected, (4) where and when the seed was planted, and (5) dates that the seed collector recommends for future seed collections.

Information on long-term seed storage is available from facilities such as the National Seed Storage Laboratory at Fort Collins, CO.

APPENDIX C:

PLANT INFORMATION NETWORK

The Plant Information Network (PIN) is a computer-based data bank designed for rapidly storing, organizing, and retrieving information on the native and naturalized vascular plants of several selected western states. The system now has information on more than 5000 plants found in Colorado, Montana, North Dakota, Utah, and Wyoming. In the near future, the system will include Arizona and New Mexico.

PIN's information units are called "descriptors" and "descriptor states." Descriptors correspond to a plant attribute that has been entered into the system. They are divided into mutually exclusive categories, or descriptor states, which represent possible ratings that a plant may be given for each attribute. For example, descriptor states for the descriptor GROWTH ON MODERATE SLOPES are *good*, *fair*, or *poor*.

Currently, PIN has information on more than 500 descriptors listed under the general headings of taxonomic, geographic, biologic, ecologic, and economic plant attributes. The taxonomic, geographic, and biologic descriptors are scored for all plants in the data bank; however, many of the ecologic and economic descriptors have been examined only for plants identified as important for reclamation, rangeland, wildlife habitat, legal status, or other resource management concerns. These plants are referred to as "priority species."

The information contained in the data bank is from a variety of sources, including:

1. Herbarium specimen labels from major herbaria in states. System information obtained from these labels includes county records, elevation ranges, and anthesis data. (For example, beginning of anthesis -- the earliest observed month of flowering for angiosperms or pollination for gymnosperms in Colorado, Montana, North Dakota, or Wyoming. Anthesis -- the mode of flowering for angiosperms in Colorado, Montana, North Dakota, or Wyoming as determined from herbarium specimens for the respective states. End of anthesis -- the latest observed month of flowering for angiosperms or pollination for gymnosperms, in Colorado, Montana, North Dakota, or Wyoming.)

2. Popular, scientific, and other professional literature. These references are reviewed largely for taxonomic and biologic descriptors, but also provide information on many ecologic and economic attributes.

3. Consultation with experts in the plant sciences. The judgment and experience of reputable professionals provide information on vegetation structure, environmental relationships, reclamation potentials, and values for wildlife and livestock.

The information which can be obtained from PIN has a variety of uses. Past and potential applications include:

1. Fairly site-specific plant lists that can help the user conduct vegetation inventories, ecological research, and other field studies.

2. The ecologic and economic values of plants can be used to prepare land management plans and enviromental assessments.

3. The information on adaptability and desirability of plants for revegetation of disturbed lands can help the manager formulate or review reclamation plans.*

4. The distribution and habitat data on rare and endangered species in the data bank can help verify their presence or absence.

The PIN system can be beneficial, particularly to military installations in the west. Present information on western plants is often incomplete, highly scattered, published in a variety of formats, and inconsistently available. Therefore, much useful information is either inaccessible or is expensive and time-consuming to collect, organize, integrate, and update. The PIN system solves many of these problems; following are some of its advantages:

1. Accessibility is simple and convenient. Requests for information are normally processed within 2 days.

2. The desired information can be retrieved by using any combination of attributes to obtain a specific subset of data.

3. Printouts can be formatted in a number of ways; thus, data presentation is more meaningful.

4. The data can be updated continuously as new information becomes available.

5. Currently, there is no cost for data retrieval. In the future, there will be a fee, but it will be only a fraction of what it would cost to get the information through more conventional methods (i.e., library searches and literature review).

Solving problems associated with rehabilitation of severely disturbed land, land-use planning, land management, environmental assessments, and protection of culturally important plants is more complex than obtaining and organizing the data; however, use of the PIN system will improve the understanding, management, and conservation of western ecosystems. The following publications further explain PIN.

Vories, K. C., and P. I. Sims, 1977, The Plant Information Network: Volume I: A User's Guide, USDI Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO, pp 1-56, FWS/OBS-77/38. (2nd edition in preparation; available September 1981.)

An introductory guide to the PIN system; describes the language, content, information sources, and potential applications of the data bank.

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* This application can be particularly useful to the military installations.

Vories, K. C., and P. I. Sims, 1977, The Plant Information Network: Volume III: Reclamation and PIN in the Powder River Basin of Montana and Wyoming, USDI Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO, pp 109-160, FWS/OBS-77/40.

A handbook demonstrating the use of PIN as a reclamation tool in the Powder River Basin of Wyoming and Montana.

Evans, G., and K. C. Vories, 1977, The Plant Information Network: Volume IV: A Subject Guide and Annotated Bibliography to Selected Literature on Land Reclamation and Rehabilitation in the Western United States, USDI Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO, pp 161-231, FWS/OBS-77/41.

A compilation and annotation of 368 reclamation literature citations indexed under 37 major subjects.

Strong, P. N., The Plant Information Network: Volume V: RAPIR Systems Manual Version 15, USDI Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO.

A programmer's manual documenting the RAPIR software used by PIN.

Strong, P. N., The Plant Information Network: Volume VI: RAPIR User's Manual. Version 15, USDI Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO, in press.

A technician's manual describing how to construct, correct, and query a data bank using the RAPIR software.

Houston, W. R., D. O. Meeker, G. D. Bryant, M. R. Olson, and K. C. Vories, The Plant Information Network: Volume VII: Reclamation and PIN in Western North Dakota, USDI Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO, in press.

A handbook demonstrating the use of PIN as a reclamation tool in western North Dakota.

Meeker, D. O., and M. R. Olson, The Plant Information Network: Volume VIII: Reclamation and PIN in Southern Utah, USDI Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO.

A handbook demonstrating the use of PIN as a reclamation tool in southern Utah.

Copies of publications can be obtained by contacting:

Publication Distribution Manager
USDI Fish and Wildlife Service
Western Energy and Land Use Team
Drake Creekside One
2625 Redwing Road
Fort Collins, CO 80526
Commercial Telephone (303) 226-9311; FTS 323-5311

To obtain a PIN search, contact:

Mike Olson
(404) 226-9389
FTS (404) 323-5389

The following printouts provided by PIN are for short-term revegetation species for soil stabilization on dry sites in the Fort Carson area, and the cultural* information available for those species.

* When cultural data are provided, copies of a bibliography containing cited references will also be included.

COLUMNS 7.-2.36=3.-1.32.-1.7.-2.1.1.1.-2.5.-1.5.-2.13*

PRINT. HABIT. GENUS. SPECIES. INFRASPECIFIC. COMMON NAME. ORIGIN. EL PASO-CO. PUEBLO-CO. FREMONT-CO. MINIMUM ELEVATION-CO. MAXIMUM ELEVATION-CO. HABITAT FOR PLANTS WITH (EL PASO-CO. PRESENT OR REPORTED OR PUEBLO-CO. PRESENT OR REPORTED OR FREMONT-CO. PRESENT OR REPORTED) AND HABITAT. DRY OR DRY-MOIST OR DRY-MOIST-WET AND WEEDINESS. COLONIZING OR NON-WEEDY AND EROSION CONTROL POTENTIAL-CO. HIGH OR MEDIUM AND ESTABLISHMENT REQUIREMENTS-CO. LOW OR MEDIUM AND SHORT-TERM REVEGETATION POTENTIAL-CO. HIGH OR MEDIUM*

COLUMN DESCRIPTORS
A = HABIT
B = GENUS
SPECIES
INFRASPECIFIC
C = COMMON NAME
D = ORIGIN
E = EL PASO-CO
F = PUEBLO-CO
G = FREMONT-CO
H = MINIMUM ELEVATION-CO
I = MAXIMUM ELEVATION-CO
J = HABITAT

LIST 20

RESPONSE:

A	B	C	D	EFG	H	I	J
FORB	MELILOTUS ALBA NONE	WHITE SWEETCLOVER	EURASIA	PP	4000	8700	DRY-MOIST
FORB	MELILOTUS OFFICINALIS NONE	YELLOW SWEETCLOVER	EUROPE	P	4000	9000	DRY-MOIST
GRASSLI	AGROPYRON CRISTATUM NONE	FAIRWAY WHEATGRASS	ASIA	R	3600	9400	DRY-MOIST
GRASSLI	AGROPYRON DASYSTACHYUM DASYSTACHYUM	THICKSPIKE WHEATGRASS	NATIVE	P	4800	10000	DRY
GRASSLI	AGROPYRON ELONGATUM NONE	TALL WHEATGRASS	EURASIA	R	4800	6900	DRY-MOIST
GRASSLI	AGROPYRON SMITHII NONE	WESTERN WHEATGRASS	NATIVE	PPP	3600	10000	DRY-MOIST
GRASSLI	AGROPYRON TRACHYCAULUM UNILATERALE	BEARDED WHEATGRASS	NATIVE	PPP	4000	10500	DRY-MOIST
GRASSLI	BROMUS INERMIS INERMIS	SMOOTH BROME	EURASIA	RP	4500	10000	DRY-MOIST
GRASSLI	BROMUS MARGINATUS NONE	BIG MOUNTAIN BROME	NATIVE	P	5000	10100	DRY-MOIST
GRASSLI	CALAMOVILFA LONGIFOLIA NONE	PRAIRIE SANDREED	NATIVE	PP	3500	9800	DRY
GRASSLI	DACTYLIS GLOMERATA NONE	ORCHARDGRASS	EURASIA	PPP	4500	10500	DRY-MOIST
GRASSLI	ELYMUS CANADENSIS NONE	CANADA WILDRYE	NATIVE	PP	3500	9000	DRY-MOIST-WET
GRASSLI	FESTUCA ARIZONICA NONE	ARIZONA FESCUE	NATIVE	P P	6500	11600	DRY-MOIST
GRASSLI	FESTUCA IDAHOENSIS NONE	IDAHO FESCUE	NATIVE	P	5800	12000	DRY-MOIST
GRASSLI	POA PRATENSIS NONE	KENTUCKY BLUEGRASS	EURASIA	PPP	4000	12200	DRY-MOIST
GRASSLI	SORGHASTRUM NUTANS NONE	YELLOW INDIANGRASS	NATIVE	P R	3500	6800	DRY
GRASSLI	SPOROBOLUS CRYPTANDRUS NONE	SAND DROPSEED	NATIVE	PPR	3500	9400	DRY
SHRUB	MAHONIA REPENS NONE	CREEPING BARBERRY	NATIVE	PP	5500	10700	DRY-MOIST
SHRUB	POTENTILLA FRUTICOSA NONE	BUSH CINQUEFOIL	NATIVE	P	5400	12100	DRY-MOIST
TREE	PINUS PONDEROSA NONE	PONDEROSA PINE	NATIVE	PPP	5400	9300	DRY

NO. OF ITEMS IN QUERY RESPONSE = 20
NO. OF ITEMS IN THE DATA BANK = 4884
PERCENTAGE OF RESPONSE/TOTAL DATA BANK = .410

COLUMNS 10.-2.38=3.-1.4(1.-1).-2.5(1.-1).-2.5(1.-1).-2.3(1.-1).-2.1.-1.1.-3.7.-2.10*

PRINT. HABIT. GENUS. SPECIES. INFRASPECIFIC. EROSION CONTROL POTENTIAL-CO. ESTABLISHMENT REQUIREMENTS-CO. SHORT-TERM REVEGETATION POTENTIAL-CO. LONG-TERM REVEGETATION POTENTIAL-CO. MULE DEER COVER VALUE. ANTELOPE COVER VALUE. GAME BIRD COVER VALUE. SMALL NON-GAME BIRD COVER VALUE. SMALL MAMMAL COVER VALUE. MULE DEER FOOD VALUE. ANTELOPE FOOD VALUE. GAME BIRD FOOD VALUE. SMALL NON-GAME BIRD FOOD VALUE. SMALL MAMMAL FOOD VALUE. CATTLE FORAGE PALATABILITY-CO. SHEEP FORAGE PALATABILITY-CO. HORSE FORAGE PALATABILITY-CO. ENERGY VALUE. PROTEIN VALUE. POISONOUS-LIVESTOCK. WEEDINESS FOR WITH RESULT*

COLUMN DESCRIPTORS
A = HABIT
B = GENUS
SPECIES
INFRASPECIFIC
C = EROSION CONTROL POTENTIAL-CO
D = ESTABLISHMENT REQUIREMENTS-CO
E = SHORT-TERM REVEGETATION POTENTIAL-CO
F = LONG-TERM REVEGETATION POTENTIAL-CO
G = MULE DEER COVER VALUE
H = ANTELOPE COVER VALUE
I = GAME BIRD COVER VALUE
J = SMALL NON-GAME BIRD COVER VALUE
K = SMALL MAMMAL COVER VALUE
L = MULE DEER FOOD VALUE
M = ANTELOPE FOOD VALUE
N = GAME BIRD FOOD VALUE
O = SMALL NON-GAME BIRD FOOD VALUE
P = SMALL MAMMAL FOOD VALUE
Q = CATTLE FORAGE PALATABILITY-CO
R = SHEEP FORAGE PALATABILITY-CO
S = HORSE FORAGE PALATABILITY-CO
T = ENERGY VALUE
U = PROTEIN VALUE
V = POISONOUS-LIVESTOCK
W = WEEDINESS

LIST 20

RESPONSE:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
FORB	MELILOTUS ALBA NONE	M	L	H	M	F	F	G	G	G	F	F	F	G	G	G	G	G	F	P	MINOR	COLONIZING
FORB	MELILOTUS OFFICINALIS NONE	M	L	H	L	F	F	G	G	G	F	F	F	G	G	G	G	F	F	F	MINOR	COLONIZING
GRASSLIKE	AGROPYRON CRISTATUM NONE	M	M	M	H	P	F	G	G	G	F	G	G	F	G	G	G	G	F	F	NO	NON-WEEDY
GRASSLIKE	AGROPYRON DASYSTACHYUM DASYSTACHYUM	H	M	M	H	P	P	P	F	F	F	F	F	F	F	G	F	F	F	F	NO	NON-WEEDY
GRASSLIKE	AGROPYRON ELONGATUM NONE	M	M	M	H	F	G	G	G	G	P	P	F	F	F	F	F	F	G	P	NO	COLONIZING
GRASSLIKE	AGROPYRON SMITHII NONE	H	M	M	H	F	G	F	G	G	F	F	P	F	F	G	F	G	G	F	NO	NON-WEEDY
GRASSLIKE	AGROPYRON TRACHYCAULUM UNILATERALE	M	L	M	M	P	P	F	F	F	F	P	F	F	F	G	F	G	F	P	NO	NON-WEEDY
GRASSLIKE	BROMUS INERMIS INERMIS	H	L	M	H	F	F	G	G	G	F	F	F	F	F	G	G	G	F	P	NO	NON-WEEDY
GRASSLIKE	BROMUS MARGINATUS NONE	M	L	M	M	P	P	F	F	F	F	P	F	F	F	G	G	G	F	P	NO	COLONIZING
GRASSLIKE	CALAMOVILFA LONGIFOLIA NONE	H	M	M	H	P	P	G	G	G	P	F	P	P	F	G	F	G	F	P	NO	NON-WEEDY
GRASSLIKE	DACTYLIS GLOMERATA NONE	H	L	M	H	P	P	G	G	G	F	P	F	F	F	G	G	G	F	P	NO	COLONIZING
GRASSLIKE	ELYMUS CANADENSIS NONE	M	M	M	M	P	F	G	G	G	F	P	F	F	F	F	F	F	G	F	NO	NON-WEEDY
GRASSLIKE	FESTUCA ARIZONICA NONE	H	M	M	H	P	P	F	G	G	F	P	P	F	F	G	F	G	F	P	NO	NON-WEEDY

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
GRASSLIKE	FESTUCA IDAHOENSIS NONE	M	M	M	M	P	P	F	G	G	F	F	F	F	F	G	G	G	F	F	NO	NON-WEEDY
GRASSLIKE	POA PRATENSIS NONE	H	L	H	M	P	P	G	G	G	F	F	F	F	F	G	G	G	F	P	NO	COLONIZING
GRASSLIKE	SORGHASTRUM NUTANS NONE	H	M	M	H	G	F	G	G	G	F	F	F	F	F	G	G	G	F	P	NO	NON-WEEDY
GRASSLIKE	SPOROBOLUS CRYPTANDRUS NONE	M	M	M	M	P	P	F	F	F	P	P	G	G	G	F	F	F	P	P	NO	NON-WEEDY
SHRUB	MAHONIA REPENS NONE	M	M	M	M	P	P	F	G	F	F	F	F	F	F	P	P	P	F	P	MINOR	NON-WEEDY
SHRUB	POTENTILLA FRUTICOSA NONE	M	M	M	M	F	P	G	G	G	F	P	P	F	F	P	P	P	F	P	NO	NON-WEEDY
TREE	PINUS PONDEROSA NONE	M	M	M	H	G	F	G	G	G	P	P	G	G	G	P	P	P	P	P	MINOR	NON-WEEDY

NO. OF ITEMS IN QUERY RESPONSE = 20
NO. OF ITEMS IN THE DATA BANK = 4884
PERCENTAGE OF RESPONSE/TOTAL DATA BANK = .410

END*

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MEMO  INFRASPECIFIC--
        INFRASPECIFIC NAMES REFER TO SUBSPECIES, VARIETIES OR FORMS.  WHEN A
        PLANT HAS AN INFRASPECIFIC NAME, IT IS PRINTED IMMEDIATELY AFTER THE
        SPECIES NAME.  IF NO INFRASPECIFIC NAME IS RECOGNIZED, THE WORD "NONE"
        IS PRINTED.  OCCASIONALLY P.I.N. OBTAINS COUNTY RECORDS FOR PLANTS WHICH
        HAVE NOT BEEN KEYED OUT TO VARIETY OR SUBSPECIES.  IN SUCH INSTANCES,
        THE WORD "UNKNOWN" IS PRINTED AFTER THE SPECIES NAME, INDICATING WE ARE
        UNCERTAIN WHICH INFRASPECIES THE RECORD SHOULD BE TIED TO*

COLUMNS 0,0,10,-2,38=3,-1,32,0,0,-2*

PRINT, HABIT, GENUS, SPECIES, INFRASPECIFIC, COMMON NAME, CULTURE FOR PLANTS
    WITH (EL PASO-CO, PRESENT OR REPORTED OR PUEBLO-CO, PRESENT OR REPORTED OR F
REMONT-CO, PRESENT OR REPORTED) AND HABITAT, DRY OR DRY-MOIST OR DRY-MOIST-WET
AND WEEDINESS, COLONIZING OR NON-WEEDY AND EROSION CONTROL POTENTIAL-CO, HIGH OR
 MEDIUM AND ESTABLISHMENT REQUIREMENTS-CO, LOW OR MEDIUM AND
SHORT-TERM REVEGETATION POTENTIAL-CO, HIGH OR MEDIUM*

COLUMN  DESCRIPTORS
A = HABIT
B = GENUS
    SPECIES
    INFRASPECIFIC
C = COMMON NAME

          LIST    20
RESPONSE:
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66

A	B	C
FORB	MELILOTUS ALBA NONE	WHITE SWEETCLOVER
	CULTURE:UNKNOWN	
FORB	MELILOTUS OFFICINALIS NONE	YELLOW SWEETCLOVER
	CULTURE:UNKNOWN	
GRASSLIKE	AGROPYRON CRISTATUM NONE	FAIRWAY WHEATGRASS

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  CULTURE:
  PROCUREMENT
    SEEDS/UNIT WT-- 19,450/OZ, 685/G (FAIRWAY) AND 11,340-12,925/OZ,
       400-455/G (STANDARD) (AOSA, 1978), 440,000/KG (HEADY, 1975),
       200,000/LB (VALLENTINE, 1971--HAFENRICHTER ET AL., 1968--COOPER ET AL.,
       1975), 204,000/LB (ATKINS AND SMITH, 1967), 32,000/LB (FAIRWAY AND
       190,000/LB (STANDARD) (WHEELER AND HILL, 1957), 175,000/LB (STEFFERUD,
       1948), 165,000-200,000 (HOOVER ET AL., 1947)
    SEED MATURITY-- JUL 11-AUG 30 (ATKINS AND SMITH, 1967), EARLY SUMMER
       (COOPER ET AL., 1957), LATE JUN IN CENTRAL PLAINS (WHEELER AND
       HILL, 1957--HOOVER ET AL., 1947)
    METHOD OF COLLECTION-- COMBINE PREFERRED, WINDROWER CAN ALSO BE USED
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(ATKINS AND SMITH, 1967). COMBINE DIRECTLY, HARVEST WITH A BINDER OR HEADER, OR WITH A SWATHER AND A PICKUP ATTACHMENT COMBINE (HARMOND ET AL., 1961--WHEELER AND HILL, 1957--ARCHER AND BUNCH, 1953--HOOVER ET AL., 1948--HOOVER ET AL., 1947). COMBINE (COOPER ET AL., 1957). BINDER OR COMBINE (WOLFF, 1951). GRAIN BINDER (WHEELER, 1950)

METHOD OF CLEANING-- HAMMERMILL TO BREAK UP SEED CLUSTER THEN CLEAN WITH A FANNING MILL (WHEELER AND HILL, 1957--KEIM AND NEWELL, 1955). FANNING MILL (ARCHER AND BUNCH, 1953--WHEELER, 1950)

PRETREATMENT

DURATION OF GOOD VIABILITY-- 12 YEARS (HAFENRICHTER ET AL., 1968). 2 YEARS OR MORE (WHEELER AND HILL, 1957). 5 YEARS OR MORE (HULL AND PEARSE, 1943A). GREATER THAN 58 MONTHS (MCALISTER, 1943). 4 YEARS (LOVE AND HANSON, 1932)

STRATIFICATION-- KNO3 AND PRECHILL AT 5 DEG. C OR 10 DEG. C FOR 7 DAYS (AOSA, 1978). PRECHILL 4 DAYS AT 6 DEG. C (POTTER, 1951). 10 DEG. C DARK FOR 7 DAYS (ANDERSEN AND DRAKE, 1944). PRECHILL 6 DAYS AT 8-10 DEG. C (HAY, 1936). PRECHILL 4 DAYS AT 6-8 DEG. C (HAY, 1935)

LABORATORY GERMINATION

TEMPERATURE-- (A) CONSTANT-- 20 DEG. C (MCGINNIES, 1960A). 15-20 DEG. C (POTTER, 1951). 15 DEG. C (ANDERSEN AND DRAKE, 1944). 19-21 DEG. C (HAY, 1935). (B) FLUCTUATING-- 15-25 DEG. C AND 20-30 DEG. C AT 16-8 HOURS (AOSA, 1978; USDA, 1952). 20-30 DEG. C AT 16-8 HOURS (POTTER, 1951). 20-30 DEG. C, 10-30 DEG. C, 15-30 DEG. C, AND 15-25 DEG. C AT 18-6 HOURS (ANDERSEN AND DRAKE, 1944). 14-17 DEG. C AND 20-22 DEG. C AT 16-8 HOURS (HAY, 1936)

MOISTURE-- (A) OPTIMUM-- UP TO 7 1/2 ATM (MCGINNIES, 1960A)

LIGHT-- LIGHT OPTIONAL (AOSA, 1978). LIGHT REQUIRED (REQUIRED (USDA, 1952)

GERMINATIVE ENERGY-- 69 P.C. IN 7 DAYS (WOLFF, 1951)

GERMINATIVE CAPACITY-- 85 P.C. (HAFENRICHTER ET AL., 1968--WHEELER AND HILL, 1957--STEFFERUD, 1948). 86 P.C. (WOLFF, 1951)

CULTURAL PRACTICES

PLANTING DEPTH-- 1.8 CM (LUDWIG, 1976). 1/2 IN. ON SANDY LOAMS, 1/4 IN. IF THE SOIL IS HIGH IN CLAY (LANG ET AL., 1975. 1/2 IN. (HULL, 1964, 1948--HULL ET AL., 1958--MCWILLIAMS, 1955--ROGLER, 1954--HULL AND DORAN, 1950--MCKENZIE ET AL., 1946). 3/4-1 IN. (ALLRED AND NIXON, 1955). 1/2-1 IN. (ARCHER AND BUNCH, 1953). 1/4 IN. (PLUMMER, 1943). LESS THAN 1 IN. (HERMANN AND HERMANN, 1939). 1/4-1/2 IN. (LOVE AND HANSON, 1932)

PLANTING TIME-- EARLY SPRING (LUDWIG, 1976). FALL ON SIEROZEM SOILS AND FALL OR EARLY SPRING ON BROWN AND CHESTNUT SOILS (HAFENRICHTER ET AL., 1968). FIRST 2 WEEKS OF APR (BEMENT ET AL., 1965). BEST RESULTS FROM FALL PLANTINGS (KILCHER, 1961). FALL (DOUGLAS ET AL., 1960). APR 1 (MCGINNIES, 1960B). SEP 20 (MCWILLIAMS, 1955). EARLY FALL (FRISCHKNECHT, 1951). FROM SEP UNTIL COLD WEATHER OR SPRING IN SOUTHERN PART OF RANGE (HOOVER ET AL., 1948). LATE SUMMER OR EARLY FALL (HULL, 1948). SEP-OCT AND FEB-MAR (STEFFERUD, 1948). SPRING PREFERABLE TO FALL (HOOVER, 1939)

EXPOSURE-- FAIRLY SHADE TOLERANT (PLUMMER ET AL., 1968)

SOIL TEXTURE-- ADAPTED TO LOAMY, CLAYEY (HEADY, 1975--STEFFERUD, 1948). CLAYEY-GOOD, SILTY-GOOD, SANDY-FAIR (VALLENTINE, 1971). SILT OR CLAY (ATKINS AND SMITH, 1967). LIGHT SANDY LOAMS TO HEAVY CLAYS (ROGLER, 1962--WALKER, 1950--STEWARD AND WALKER, 1939)

SOIL MOISTURE-- LOW MOISTURE REQUIREMENT (COOPER ET AL., 1957). MODERATE TO DRY (HULL AND JOHNSON, 1955)

PRECIPITATION-- 5-14 IN. ANNUAL (LONG ET AL., 1975). 10 IN. OR MORE ANNUAL (USDA, FOR. SER., 1966). 11-16 IN. ANNUAL (JEFFERIES AND CARDWELL, 1964). ANNUAL RAINFALL MORE THAN 17 IN. (USDA, FOR. SER., 1937)

DRAINAGE-- WELL DRAINED (USDA, FOR. SER., 1966--PLUMMER ET AL., 1943--STEWART AND WALKER, 1939)

GRASSLIKE AGROPYRON DASYSTACHYUM DASYSTACHYUM THICKSPIKE WHEATGRASS

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 154,000/LB (WHEELER AND HILL, 1957--STEFFERUD, 1948)
METHOD OF COLLECTION-- MAY BE COMBINED (WHEELER AND HILL, 1957)
LABORATORY GERMINATION
TEMPERATURE-- (A) CONSTANT-- 10 DEG. C FOR 3 DAYS THEN 20 DEG. C (HAFERKAMP AND MCSWAIN, 1951)
GERMINATIVE CAPACITY-- 85 P.C. (WHEELER AND HILL, 1957)
CULTURAL PRACTICES
SOIL TEXTURE-- MODERATELY COARSE TEXTURED (HAFENRICHTER ET AL., 1968). SANDY (USDA, FOR. SER., 1937)
SOIL MOISTURE-- MOIST (HULL AND JOHNSON, 1955)
PRECIPITATION-- 5-9 IN. ANNUAL (LANG ET AL., 1975)
DRAINAGE-- WELL-DRAINED (HULL AND JOHNSON, 1955)

GRASSLIKE AGROPYRON ELONGATUM NONE TALL WHEATGRASS

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 4,650-4,750/LB, 400-455/G (AOSA, 1978). 175,000/KG (HEADY, 1975). 79,000 (VALLENTINE, 1971--ATKINS AND SMITH, 1967--WHEELER AND HILL, 1957--STEFFERUD, 1948). 80,000 (COOPER ET AL., 1957)
SEED MATURITY-- JUL 16-AUG 30 (ATKINS AND SMITH, 1967). EARLY FALL (COOPER ET AL., 1957)
METHOD OF COLLECTION-- COMBINE PREFERRED. ALSO BINDER (ATKINS AND SMITH, 1968). HARVEST WITH A BINDER (WHEELER AND HILL, 1957)
PRETREATMENT
STRATIFICATION-- KNO3 AND PRECHILL AT 5 DEG. C FOR 5 DAYS (AOSA, 1978)
SCARIFICATION-- PIERCE INTEGUMENTARY LAYER OF CARYOPSIS WITH SHARP NEEDLE (THORNTON, 1966B)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 15-25 DEG. C AND 20-30 DEG. C AT 16-8 HOURS (AOSA, 1978). 15-30 DEG. C 16-8 HOURS (THORNTON, 1966B)
LIGHT-- REQUIRED AT 20-30 DEG. C, OPTIONAL AT 15-25 DEG. C (AOSA, 1978)
GERMINATIVE CAPACITY-- 90 P.C. (ATKINS AND SMITH, 1967--WHEELER AND HILL, 1957, STEFFERUD, 1948). 89 P.C. (COOPER ET AL., 1957)
CULTURAL PRACTICES
PLANTING DEPTH-- 1/2 IN. (MCKENZIE ET AL., 1946)
PLANTING TIME-- EARLY SPRING IF IRRIGATED, AUG 15-SEP 15 BELOW 4,000 FEET (HAFENRICHTER ET AL., 1968). EARLY FALL (FRISCHKNECHT, 1951)
SOIL TEXTURE-- ADAPTED TO LOAMY, CLAY (HEADY, 1975). SILTY-GOOD, CLAYEY-GOOD, SANDY-POOR (VALLENTINE, 1971). SILT OR CLAY (ATKINS AND SMITH, 1967)
SOIL PH-- ADAPTED TO ALKALI (HEADY, 1975--HAFENRICHTER ET AL., 1968). 4.7-9.5 (MOYER AND SEAMONDS, 1975). PARTICULARLY ADAPTED TO SALINE OR ALKALI SOILS (KEIM AND NEWELL, 1955)

SOIL MOISTURE-- ADAPTED TO WET (HEADY, 1975--KEIM AND NEWELL, 1955). HIGH MOISTURE REQUIREMENT (COOPER ET AL., 1957)
PRECIPITATION-- 5-9 IN. ANNUAL (LANG ET AL., 1975). AT LEAST 14 IN. MEAN ANNUAL (HAFENRICHTER ET AL., 1968). 17+ IN. ANNUAL (JEFFERIES AND CARDWELL, 1964)
DRAINAGE-- PREFORMS WELL IN POORLY DRAINED (MOYER AND SEAMANDS, 1975). POORLY DRAINED (KEIM AND NEWELL, 1962)

GRASSLIKE AGROPYRON SMITHII NONE WESTERN WHEATGRASS

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 7,115/OZ, 250/G (AOSA, 1978). 243,000/KG (HEADY, 1975). 126,000/LB (VALLENTINE, 1971--ATKINS AND SMITH, 1967). 110,000/LB (HAFENRICHTER ET AL., 1968--WHEELER AND HILL, 1957--STEFFERUD, 1948). 125,000/LB (COOPER ET AL., 1957). 100,000-125,000/LB (HOOVER ET AL., 1957)
SEED MATURITY-- JUL 16-AUG 30 (ATKINS AND SMITH, 1967). LATE SUMMER (COOPER ET AL., 1957). LATE AUG AND EARLY SEP (WHEELER, 1950). AUG 1 IN NORTH, EARLIER IN SOUTH (HOOVER ET AL., 1947). MOST SEED MATURES BY SEP (SAMPSON, 1924)
METHOD OF COLLECTION-- WINDROWER (ATKINS AND SMITH, 1967). COMBINE (COOPER ET AL., 1957). COMBINE, WINDROWING FOLLOWED BY PICKUP THRESHING, HEADING FOLLOWED BY STACKING AND THRESHING, STRIPPER (WHEELER AND HILL, 1957--WOLFF, 1951). COMBINE DIRECTLY OR HARVEST WITH A BINDER OR HEADER OR WITH A SWATHER AND PICKUP ATTACHMENT (ARCHER AND BUNCH, 1953--HOOVER ET AL., 1947)
METHOD OF CLEANING-- RUN SEEDS OVER A SCALPER TO REMOVE STEMMY MATERIAL. REMOVE AWNS WITH A HAMMERMILL (WHEELER AND HILL, 1957)
PRETREATMENT
DURATION OF GOOD VIABILITY-- 2-4 YEARS (ARCHER AND BUNCH, 1953). 4 YEARS (HULL AND PEARSE, 1943A). 51 MONTHS (MCALISTER, 1943)
SCARIFICATION-- REMOVE DISTAL END OF SEED BY CUTTING THROUGH THE LEMMA AND PALEA AND A SMALL PORTION OF THE CARYOPSIS (KINCH, 1966)
LABORATORY GERMINATION
TEMPERATURE-- (A) CONSTANT-- 60 DEG. F (KNIPE, 1973). (B) FLUCTUATING-- 15-30 DEG. C AT 16-8 HOURS (AOSA, 1978). 24-13 DEG. C AT 12-12 HOURS (ROKHARI ET AL., 1975). 60-80 DEG. F (KNIPE, 1973). 20-30 DEG. C AT 16-8 HOURS (USDA, 1952). 17-30 DEG. C, 20-30 DEG. C (NORRIS AND DECKER, 1944). 20-30 DEG. C AT 18-6 HOURS (HAY, 1938)
MOISTURE-- (A) OPTIMUM-- 0 ATM (KNIPE, 1973). (B) LOWER LIMIT-- -7 BARS (ROKHARI ET AL., 1975)
LIGHT-- WHITE LIGHT INHIBITS GERMINATION, RED LIGHT AT 4 AND 8 MINUTE EXPOSURES STIMULATES GERMINATION (SCHULTZ AND KINCH, 1976). GERMINATION PROMOTED BY RED LIGHT (TOOLE, 1976). GERMINATION INHIBITED BY LIGHT (MAYER AND POLJAKOFF-MAYBER, 1975). INDEPENDENT OF LIGHT (KNIPE, 1973). HIGHER GERMINATION PERCENTAGES IN DARK (DELOUCHE AND BASS, 1954). LIGHT REQUIRED (USDA, 1952)
GERMINATIVE ENERGY-- 86 P.C. IN 30 DAYS (HAY, 1938)
GERMINATIVE CAPACITY-- 60 P.C. (HAFENRICHTER ET AL., 1968). 75 P.C. (ATKINS AND SMITH, 1967). 56 P.C. (COOPER ET AL., 1957). 80 P.C. ONE YEAR AFTER HARVEST (WHEELER AND HILL, 1957--WOLFF, 1951). 70 P.C. (ARCHER AND BUNCH, 1953). 80 P.C. (WHEELER, 1950--HOOVER ET AL., 1947). 50-80 P.C. (HULL AND PEARSE, 1943A)
COMMENTS-- MOISTEN SUBSTRATUM WITH 0.2 P.C. KNO3 OR GERMINATE IN SOIL

(AOSA, 1978)
CULTURAL PRACTICES
PLANTING DEPTH-- 3/4-1 IN. (ALLRED AND NIXON, 1955). 1/2-1 IN. (MCWILLIAMS, 1955). 1 IN. (ARCHER AND BUNCH, 1953). 1 IN. (STEFFERUD, 1948). 3/4 IN. (PLUMMER, 1943)
PLANTING TIME-- EARLY FALL (MCWILLIAMS, 1955)--SEP-OCT, FEB-MAR (STEFFERUD, 1948)
EXPOSURE-- NOT HIGHLY SHADE TOLERANT (PLUMMER ET AL., 1955)
SOIL TEXTURE-- ADAPTED TO SANDY, LOAMY CLAY (HEADY, 1975). SILTY-GOOD, CLAYEY-GOOD, SANDY-POOR (VALLENTINE, 1971). SILT OR CLAY (ATKINS AND SMITH, 1967). BEST ADAPTED TO CLAY (DONAHUE ET AL., 1956). CLAY TO LOAM (ALLRED AND NIXON, 1955). LOAM, CLAY (STEFFERUD, 1948). FINE TEXTURED SOILS, LOAMS, SILT LOAMS, AND CLAYS (STEWART AND WALKER, 1939)
SOIL MOISTURE-- ADAPTED TO WET (HEADY, 1975). HIGH MOISTURE REQUIREMENT (COOPER ET AL., 1967). MOIST (HULL AND JOHNSON, 1955)
PRECIPITATION-- 5-14 IN. ANNUAL (LANG ET AL., 1975). 11-16 IN. ANNUAL (JEFFERIES AND CARDWELL, 1964). IN EXCESS OF 12 IN. ANNUAL (PLUMMER ET AL., 1943)
DRAINAGE-- WELL-DRAINED BOTTOM LANDS (JOHNSON, 1976--JUDD, 1962--USDA, FOR. SER., 1937--SAMPSON, 1924)
COMMENTS-- (A) GREENHOUSE-- SIGNIFICANT TEMPERATURE LEVEL OF MOISTURE STRESS INTERACTION (KNIPE, 1973)

GRASSLIKE AGROPYRON TRACHYCAULUM UNILATERALE BEARDED WHEATGRASS

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 150,000/LB (HAFENRICHTER ET AL., 1968--WHEELER AND HILL, 1957). 117,000/LB (STEFFERUD, 1948)
SEED MATURITY-- BETWEEN JUL AND SEP (SAMPSON, 1924)
LABORATORY GERMINATION
TEMPERATURE-- (A) FLUCTUATING-- 20-30 DEG. C AT 16-8 HOURS (HAFERKAMP AND MCSWAIN, 1951)
LIGHT-- LIGHT REQUIRED (HAFERKAMP AND MCSWAIN, 1951)
GERMINATIVE CAPACITY-- 95 P.C. (HAFENRICHTER, ET AL., 1968). 96 P.C. (WHEELER AND HILL, 1957)
CULTURAL PRACTICES
EXPOSURE-- SHADE TOLERANT (PLUMMER ET AL., 1955)
SOIL TEXTURE-- SANDY (USDA, FOR. SER., 1937--SAMPSON, 1924)
SOIL MOISTURE-- FAIRLY MOIST (SAMPSON, 1924)

GRASSLIKE BROMUS INERMIS INERMIS SMOOTH BROME

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 8,475-9,385/OZ, 300-330G (AOSA, 1978). 275,000/KG (HEADY, 1975). 145,000/LB (VALLENTINE, 1971--ATKINS AND SMITH, 1967--COOPER ET AL., 1957). 135,000/LB (WHEELER AND HILL, 1957). 179,000-200,000/LB (HOOVER ET AL., 1948). 136,000/LB (STEFFERUD, 1948)
SEED MATURITY-- JUL 16-AUG 30 (ATKINS AND SMITH, 1967). EARLY SUMMER

(COOPER ET AL., 1957). EARLY JUL IN IL (WHEELER AND HILL, 1957). MID SUMMER (HOOVER ET AL., 1948--HOOVER ET AL., 1947)

METHOD OF COLLECTION-- COMBINE PREFERRED. ALSO WINDROWER (ATKINS AND SMITH, 1967). BINDER OR COMBINE (NEWELL AND ANDERSON, 1962--ARCHER AND BUNCH, 1953--WOLFF, 1951--CHRUCH, 1944). COMBINE PREFERRED, ALSO BINDER (COOPER ET AL., 1957--WHEELER, 1950). DIRECT COMBINING, BINDER IF CROP BADLY LODGED (HARMOND ET AL., 1957). HARVEST WITH A COMBINE (WHEELER AND HILL, 1957). BINDER OR SMALL-GRAIN COMBINE (HOOVER ET AL., 1948--HOOVER ET AL., 1947--FROLIK AND NEWELL, 1941)

METHOD OF CLEANING-- FANNING MILL OR THREE-SCREEN MILL (WOLFF, 1951). FANNING MILL (HOOVER ET AL., 1948--HOOVER ET AL., 1947--CHURCHILL, 1944--FROLIK AND NEWELL, 1941)

PRETREATMENT

METHOD OF STORAGE-- STORE AT 5 DEG. C WITH 40 P.C. RELATIVE HUMIDITY (CANODE, 1965). MOISTURE CONTENT SHOULD BE REDUCED TO LESS THAN 12 P.C. (GRABE, 1957)

DURATION OF GOOD VIABILITY-- ABOUT 4 YEARS (WHEELER AND HILL, 1957--WOLFF, 1951). 5 YEARS (MCWILLIAMS, 1950--HULL AND PEARSE, 1943A). 22 MONTHS (MCALISTER, 1943)

STRATIFICATION-- PRECHILL 5 DAYS AT 10 DEG. C (GRABE, 1955--GRABE AND BASS, 1954)

LABORATORY GERMINATION

TEMPERATURE-- (A) CONSTANT-- 20 DEG. C (MCGINNIES, 1970, 1960A). (B) FLUCTUATING-- 20-30 DEG. C AT 16-8 HOURS (AOSA, 1978--USDA, 1952)

MOISTURE-- (A) OPTIMUM-- UP TO 7 1/2 ATM (MCGINNIES, 1960A)

LIGHT-- LIGHT OPTIONAL (AOSA, 1978--USDA, 1952). LIGHT BENEFICIAL (GRABE AND BASS, 1954)

GERMINATIVE ENERGY-- 50 P.C. IN 7 DAYS (GRABE, 1956). 65 P.C. IN 7 DAYS (WOLFF, 1951)

GERMINATIVE CAPACITY-- 83 P.C. (ATKINS AND SMITH, 1967). 81 P.C. (COOPER ET AL., 1957). 80-90 P.C. (WHEELER AND HILL, 1957). 90 P.C. (KEIM AND NEWELL, 1955). 90 P.C. (ARCHER AND BUNCH, 1953--HOOVER ET AL., 1947). 85 P.C. (WOLFF, 1951--STEFFERUD, 1948). 85 P.C. TO ABOVE 95 P.C. (HULL AND PEARSE, 1943A)

CULTURAL PRACTICES

PLANTING DEPTH-- NO DEEPER THAN 1 IN. (ROGER ET AL., 1961). 1/2-1 IN. (MCWILLIMAS, 1955). 1/2-3/4 IN. (ARCHER AND BUNCH, 1953--FROLIK AND NEWELL, 1941). 1/4-1/2 IN. (WHEELER, 1950). 1/2 IN. (MCKENZIE ET AL., 1946)

PLANTING TIME-- FALL (NEWELL AND ANDERSON, 1962). APR 1 (MCGINNIES, 1960B). SEP 5 (MCWILLIAMS, 1955). EARLY FALL (ARCHER AND BUNCH, 1953--FRISCHKNECHT, 1951). SPRING OR LATE FALL (USDA, FOR. SER., 1937)

EXPOSURE-- TOLERATES SHADE (PLUMMER ET AL., 1968). GROWS WELL IN SHADE OR SUN (PLUMMER ET AL., 1955)

SOIL TEXTURE-- ADAPTED TO SANDY, LOAMY (HEADY, 1975). SILTY-GOOD, CLAYEY-GOOD, SANDY-GOOD TO FAIR (VALLENTINE, 1971). SILT OR CLAY (ATKINS AND SMITH, 1967). SILT LOAMS OR CLAY LOAMS (NEWELL AND ANDERSON, 1962). DEEP SILT LOAMS ARE BEST, ALSO LIGHT SANDY SOILS (WHEELER, 1950--FROLIK AND NEWELL, 1941). CLAY LOAM (HOOVER ET AL., 1948--USDA, FOR. SER., 1937). LOAMS AND CLAY LOAMS (ANDERSON, 1941). PREFERS RICH LOAMS AND CLAY LOAMS BUT WILL SUCCEED ON SANDY SOILS (STEWART AND WALKER, 1939--PIPER, 1934, 1924)

SOIL DEPTH-- DEEP (BEARD, 1973--NEWELL AND ANDERSON, 1962). NOT TOO SHALLOW (FORSLING AND DAYTON, 1931). RATHER DEEP (USDA, FOR. SER., 1931)

SOIL MOISTURE-- ADAPTED TO WET (HEADY, 1975). HIGH MOISTURE REQUIREMENT (COOPER ET AL., 1957). MOIST (HULL AND JOHNSON, 1955--HOOVER ET AL., 1948--USDA, FOR. SER., 1937). FAIRLY MOIST (FORSLING AND DAYTON, 1931)

PERCIPITATION-- 15+ IN. ANNUAL (LANG ET AL., 1975--JEFFERIES AND CARDWELL, 1964). MEAN ANNUAL MORE THAN 15 IN. (HAFENRICHTER ET AL., 1968). 11 IN. ANNUAL IS MINIMUM (PLUMMER ET AL., 1968). ABOVE 18 IN. A YEAR (HULL AND PEARSE, 1943B)
DRAINAGE-- WELL DRAINED (BEARD, 1973--HAFENRICHTER ET AL., 1968--NEWELL AND ANDERSON, 1962--HOOVER ET AL., 1948)

GRASSLIKE BROMUS MARGINATUS NONE BIG MOUNTAIN BROME

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 4,005/OZ, 140/G (AOSA, 1978). 198,000/KG (HEADY, 1975). 70,000/LB (VALLENTINE, 1971). 60,475/LB (PLUMMER ET AL., 1968). 70,000/LB (WHEELER AND HILL, 1957). 71,000/LB (STEFFERUD, 1948)
SEED MATURITY-- AUG 1-SEP 15 (PLUMMER ET AL., 1968). MID SUMMER (HOOVER ET AL., 1948)
METHOD OF COLLECTION-- COMBINE OR HAND COLLECT (PLUMMER ET AL., 1968). BINDING OR SHOCKING AND THRESHING (WHEELER AND HILL, 1957). HARVEST WITH A BINDER OR SMALL-GRAIN COMBINE (ARCHER AND BUNCH, 1953--HOOVER ET AL., 1948)
METHOD OF CLEANING-- DRY AND FAN (PLUMMER ET AL., 1968). FANNING MILL (ARCHER AND BUNCH, 1953--HOOVER ET AL., 1948)
PRETREATMENT
DURATION OF GOOD VIABILITY-- 3 YEARS (HAFENRICHTER ET AL., 1968). 4 YEARS (HULL AND PEARSE, 1943A). MORE THAN 58 MONTHS (MCALISTER, 1943)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 20-30 DEG. C AT 16-8 HOURS (AOSA, 1978--USDA, 1952)
LIGHT-- LIGHT REQUIRED (AOSA, 1978; USDA, 1952)
GERMINATIVE CAPACITY-- 85 P.C. (STEFFERUD, 1948). 90 P.C. (HULL AND PEARSE, 1943A)
CULTURAL PRACTICES
PLANTING TIME-- APR AND MAY (ARCHER AND BUNCH, 1953). IN SPRING BEFORE MAY 10 (WHEELER, 1950)
SOIL TEXTURE-- ADAPTED TO LOAMY, CLAYEY (HEADY, 1975). SILTY-GOOD, CLAYEY-GOOD, SANDY-POOR (VALLENTINE, 1971). GROWS BEST IN LOAM SOILS BUT WILL GROW IN CLAY AND SANDY LOAMS (BRIDGES, 1942--STEWART AND WALKER, 1939)
SOIL MOISTURE-- GROWS BEST IN FAIRLY MOIST BUT WILL GROW IN MODERATELY DRY (BRIDGES, 1942--STEWART AND WALKER, 1939)
COMMENTS--(A) FIELD-- TREAT SEED WITH FUNGICIDE BEFORE PLANTING BECAUSE OF SUSCEPTIBILITY TO HEAD SMUT (HAFENRICHTER ET AL., 1968)

GRASSLIKE CALAMOVILFA LONGIFOLIA NONE PRAIRIE SANDREED

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 274,000/LB (VALLENTINE, 1971). 273,700/LB
METHOD OF COLLECTION-- COMBINE (FLORY AND MARSHALL, 1942)
METHOD OF CLEANING-- HAMMERMILL THEN SCREEN AND FAN (WEBER, 39)
PRETREATMENT

SCARIFICATION-- SCARIFY WITH SAND (HAFERKAMP AND MCSWAIN, 1951)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 20-30 DEG. C AT 16-8 HOURS (HAFERKAMP AND MCSWAIN, 1951)
GERMINATIVE CAPACITY-- 75 P.C. (STEFFERUD, 1948)
CULTURAL PRACTICES
PLANTING DEPTH-- 1 IN. (FLORY AND MARSHALL, 1942)
SOIL TEXTURE-- SANDY SOILS AND ALSO DEEP MEDIUM-TEXTURED SOILS (OHLENBUSCH, 1976). SANDY-GOOD, SILTY-FAIR, CLAYEY-POOR (VALLENTINE, 1971). SAND, SANDY LOAM (STEFFERUD, 1948). ADAPTED TO SANDY SOILS BUT ALSO GROWS WELL ON HEAVY-TEXTURED SOILS (FROLIK AND KEIM, 1938)

GRASSLIKE DACTYLIS GLOMERATA NONE ORCHARDGRASS

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 23,615-29,825/OZ, 840-1,050/G (AOSA, 1978). 1,190,000/KG (HEADY, 1975)). 540,000/LB (VALLENTINE, 1971). 650,000/LB (WHEELER AND HILL, 1957). 654,000/LB (STEFFERUD, 1948)
SEED MATURITY-- JUN 15-20 (WHEELER, 1950)
METHOD OF COLLECTION-- HARVEST WITH A BINDER OR BY DIRECT COMBINING (HARMOND ET AL., 1961--ARCHER AND BUNCH, 1953--WHEELER, 1950). HARVEST WITH A BINDER BEST (WHEELER AND HILL, 1957, CARD, 1923)
METHOD OF CLEANING-- FANNING MILL (WOLFF, 1951)
PRETREATMENT
METHOD OF STORAGE-- STORE AT 5 DEG. C WITH 40 P.C. RELATIVE HUMIDITY (CANODE, 1965)
DURATION OF GOOD VIABILITY-- 12-14 YEARS (HAFENRICHTER ET AL., 1968)
STRATIFICATION-- PRECHILL AT 5 OR 10 DEG. C FOR 7 DAYS (AOS, 1978--CANODE ET AL., 1963). PRECHILL AT 5 DEG. C FOR 5 DAYS (MAGUIRE AND CANODE, 1963). CHILL MOIST SEED AT TEMPERATURES BETWEEN 5 AND 10 DEG. C FOR 14 DAYS (SPRAGUE, 1940)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 15-25 DEG. C AT 16-8 HOURS (AOSA, 1978, CANODE ET AL., 1963--MAGUIRE AND CANODE, 1963). 20-30 DEG. C AT 16-8 HOURS (USDA, 1952). 10-30 DEG. C, 15-30 DEG. C AT 16-8 HOURS (SPRAGUE, 1940)
LIGHT-- LIGHT REQUIRED (AOSA, 1970--USDA, 1952)
GERMINATIVE ENERGY-- 30 P.C. IN 7 DAYS (WOLFF, 1951). 95 P.C. IN 14 DAYS (SPRAGUE, 1940)
GERMINATIVE CAPACITY-- 85 P.C. (WHEELER AND HILL, 1957--STEFFERUD, 1948). 90 P.C. OR BETTER (HULL AND PEARSE, 1943A). 82 P.C. (WOLFF, 1951). 97 P.C. IN 28 DAYS (SPRAGUE, 1940)
COMMENTS-- GERMINATION MORE RAPID ON SOIL (AOSA, 1978--USDA, 1952)
CULTURAL PRACTICES
PLANTING DEPTH-- NO DEEPER THAN 1 IN. (ROGLER ET AL., 1961)
PLANTING TIME-- EARLY SPRING BEST (MYERS, 1962). SPRING (WHEELER AND HILL, 1957). EARLY FALL (FRISCHKNECHT, 1951)
EXPOSURE-- HIGHLY SHADE TOLERANT (PLUMMER ET AL., 1968--HULL AND JOHNSON, 1955--PLUMMER ET AL., 1955--FROLIK AND FROLIK, 1941). GROWS WELL IN PARTIAL SHADE (ANDERSON, 1941). ADAPTED TO SHADE (PIPER, 1924)
SOIL TEXTURE-- ADAPTED TO SANDY, LOAMY (HEADY, 1975). SILTY-GOOD, CLAYEY-GOOD, SANDY-FAIR (VALLENTINE, 1971). MEDIUM-TEXTURED

(HAFENRICHTER ET AL., 1968). DOES WELL ON CLAY AND CLAY LOAM SOILS (ARCHER AND BUNCH, 1953--STEWART AND WALKER, 1939--PIPER, 1924). ADAPTED TO A WIDE VARIETY OF SOILS BUT DOES NOT DO WELL ON SANDY SOILS (ANDERSON, 1941)
SOIL PH-- CALCAREOUS, NEUTRAL, OR MEDIUM ACID (HAFENRICTHER ET AL., 1968). DOES NOT DO WELL ON VERY ALKALINE SOIL (MYERS, 1962). DOES NOT DO WELL ON ACID OR ALKALI SOILS (WHEELER AND HILL, 1957)
SOIL MOISTURE-- ADAPTED TO WET SOILS (HEADY, 1975). PREFERS MODERATE MOISTURE AND WILL GROW IN WET SOILS (STEWART AND WALKER, 1939)
PRECIPITATION-- MEAN ANNUAL PRECIPITATION AT LEAST 18 IN. (HAFENRICHTER ET AL., 1968). ANNUAL PRECIPITATION MORE THAB 12 IN. (PLUMMER ET AL., 1968)
DRAINAGE-- WELL DRAINED (HAFENRICHTER ET AL., 1968--ARCHER AND BUNCH, 1953). DOES NOT DO WELL ON POORLY DRAINED SOILS (WHEELER AND HILL, 1957)

GRASSLIKE ELYMUS CANADENSIS NONE CANADA WILDRYE

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 5,385/OZ, 190/G (AOSA, 1978). 106,000/LB (VALLENTINE, 1971--ATKINS AND SMITH, 1967). 100,000/LB (COOPER ET AL., 1957). 115,000/LB (WHEELER AND HILL, 1957--STEFFERUD, 1948). 110,000-120,000/LB - (HOOVER ET AL., 1947)
SEED MATURITY-- JUL 16-AUG 30 (ATKINS AND SMITH, 1967). EARLY FALL (COOPER ET AL., 1957). JUL IN THE SOUTH TO AUG IN THE NORTH (WHEELER AND HILL, 1957). LATE SUMMER (ARCHER AND BUNCH, 1953--WHEELER, 1950--HOOVER ET AL., 1948--HOOVER ET AL., 1947). EARLY AUG (SAMPSON, 1924)
METHOD OF COLLECTION-- COMBINE PREFERRED, ALSO BINDER (ATKINS AND SMITH, 1967). HARVEST WITH BINDER OR BY DIRECT COMBINING (HARMOND ET AL., 1961). COMBINE OR BINDER (COOPER ET AL., 1957). HARVESTED MOST SATISFACTORILY WITH BINDER (WHEELER AND HILL, 1957--HOOVER ET AL., 1948--WHEELER, 1950--HOOVER ET AL., 1947). HARVESTED MOST SATISFACTORILY WITH COMBINE (ARCHER AND BUNCH, 1953). COMBINE OR HAND HARVEST WITH A HALF-SICKLE (WOLFF, 1951)
METHOD OF CLEANING-- PROCESS IN A HAMMERMILL (WHEELER AND HILL, 1957--WOLFF, 1951--SMITH, 1946). FANNING MILL (HOOVER ET AL., 1947). MILL THRESHED SEED IN HAMMERMILL AND CLEAN WITH A SEED CLEANER (SCHWENDIMAN ET AL., 1940). HAMMERMILL THEN SCREEN AND FAN (WEBER, 1939)
PRETREATMENT
DURATION OF GOOD VIABILITY-- SELDOM EXCEEDS 2 YEARS (WOLFF, 1951). 5 YEARS (MCWILLIAMS, 1950). 3 YEARS (BLAKE, 1935)
STRATIFICATION-- PRECHILL AT 5 DEG. C FOR 2 WEEKS (AOSA, 1978)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 15-30 DEG. C AT 16-8 HOURS (AOSA, 1978). 17-30 DEG. C (NORRIS AND DECKER, 1944)
LIGHT-- LIGHT REQUIRED (AOSA, 1978)
GERMINATIVE ENERGY-- 42 P.C. IN 7 DAYS (WOLFF, 1951)
GERMINATIVE CAPACITY-- 70 P.C. (ATKINS AND SMITH, 1967). 77 P.C. (COOPER ET AL., 1957). 90 P.C. (HOOVER ET AL., 1947--ARCHER AND BUNCH, 1953--WHEELER, 1950). 70 P.C. (WHEELER AND HILL, 1957). 79 P.C. (WOLFF, 1951). 85 P.C. (STEFFERUD, 1948)
CULTURAL PRACTICES
PLANTING DEPTH-- 1/2-1 IN. (ALLRED AND NIXON, 1955). 1 IN. (MCWILLIAMS, 1955--STEFFERUD, 1948). IF THE SURFACE OF THE SOIL IS DRY--UP TO 1 IN. OR SLIGHTLY MORE IN DEPTH (WHEELER, 1950)

PLANTING TIME-- SEP 5 (MCWILLIAMS, 1955). EARLY FALL BEST. ALSO CAN BE DONE IN LATE FALL OR SPRING (WHEELER, 1950)
SOIL TEXTURE-- SANDY-GOOD, SILTY-GOOD, CLAYEY-GOOD (VALLENTINE, 1971). SAND, SILT OR CLAY (ATKINS AND SMITH, 1967). ESPECIALLY WELL ADAPTED TO SANDY SOILS (WHEELER AND HILL, 1957--WHEELER, 1950). LOAM TO SAND (ALLRED AND NIXON, 1955). SAND, SANDY LOAM (STEFFERUD, 1948)
SOIL MOISTURE-- DRY OR MOIST (BROWN, 1979). HIGH MOISTURE REQUIREMENT (COOPER ET AL., 1957). MOIST (HULL AND PEARSE, 1943B). ABUNDANT MOISTURE (FROLIK AND KEIM, 1938). 2/3 SATURATION (BLAKE, 1935)
PRECIPITATION-- 15-16 IN. ANNUAL (MT AGRIC. EXP. STA., 1970)
COMMENTS-- (A) GREENHOUSE-- MOST SEEDLINGS ARE PRODUCED WHEN SEEDS ARE PLANTED SECOND YEAR AFTER HARVEST (ROBOCKER ET AL., 1953)

GRASSLIKE FESTUCA ARIZONICA NONE ARIZONA FESCUE

CULTURE:
PROCUREMENT
SEED MATURITY-- SEP 10-SEP 22 (PEARSON, 1967) JUN 15-AUG 1 AT LOWER ELEVATIONS, BY SEP 10 AT HIGHER ELEVATIONS (SAMPSON, 1924)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 20-30 DEG. C AT 16-8 HOURS (HAFERKAMP AND MCSWAIN, 1951)
LIGHT-- LIGHT REQUIRED (HAFERKAMP AND MCSWAIN, 1951)
CULTURAL PRACTICES
EXPOSURE-- SOMEWHAT SHADE TOLERANT (SAMPSON, 1924)
SOIL TEXTURE-- CLAY LOAMS, ALSO SANDY, GRAVELLY OR ROCKY SOILS (USDA, FOR. SER., 1937)
SOIL DEPTH-- SHALLOW (USDA, FOR. SER., 1937)
SOIL MOISTURE-- DRY (USDA, FOR. SER., 1937)

GRASSLIKE FESTUCA IDAHOENSIS NONE IDAHO FESCUE

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 450,000/LB (VALLENTINE, 1971--HAFENRICHTER ET AL., 1968)
SEED MATURITY-- AUG (SAMPSON, 1924)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 10-20 DEG. C, 20-30 DEG. C AT 16-8 HOURS (HAFERKAMP AND MCSWAIN, 1951)
LIGHT-- LIGHT REQUIRED (HAFERKAMP AND MCSWAIN, 1951)
GERMINATIVE CAPACITY-- 80 P.C. (HAFENRICHTER ET AL., 1968)
CULTURAL PRACTICES
SOIL TEXTURE-- SILTY-GOOD, CLAYEY-GOOD, SANDY-FAIR (VALLENTINE, 1971). CLAY TO ROCKY, SANDY OR GRAVELLY LOAMS BEST (USDA, FOR. SER., 1937)
SOIL DEPTH-- SHALLOW TO DEEP, MODERATELY DEEP BEST (USDA, FOR. SER., 1937)
SOIL MOISTURE-- MOIST TO DRY, FAIRLY DRY BEST (USDA, FOR. SER., 1937). MODERATELY DRY (SAMPSON, 1924)
DRAINAGE-- WELL DRAINED (USDA, FOR. SER., 1937)

A B C

GRASSLIKE POA PRATENSIS NONE KENTUCKY BLUEGRASS

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 53,845-109,885/OZ. 2,250-3,875/G (AOSA, 1978). 4,754,000 /KG (HEADY, 1975). 2,150,000/LB (VALLENTINE, 1971). 2,156,000/LB (HAFENRICHTER ET AL., 1968). 2,200,000/LB (WHEELER AND HILL, 1957). 2,117,000/LB (STEFFERUD, 1948)
SEED MATURITY-- SECOND OR THIRD WEEK IN JUN IN KT AND MO (WHEELER AND HILL, 1957)
METHOD OF COLLECTION-- HARVEST BY STRIPPING (FERGUS, 1962--HARMOND ET AL., 1961--WHEELER AND HILL, 1957--WHEELER, 1950--CARD, 1923). BLUEGRASS STRIPPER (KEIM AND NEWELL, 1955). GRAIN COMBINE OR STRIPPER (ARCHER AND BUNCH, 1953)
PRETREATMENT
DURATION OF GOOD VIABILITY-- LESS THAN 4 YEARS (GARMAN AND VAUGHN, 1916)
STRATIFICATION-- PRECHILL AT 10 DEG. C FOR 5 DAYS (AOSA, 1978--USDA, 1952). CHILL MOIST SEED BETWEEN 5 AND 15 DEG. C FOR 10 DAYS (SPRAGUE, 1940)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 15-25 DEG. C AT 16-8 HOURS (AOSA, 1978--TOOLE AND BORTHWICK, 1971--CUDDY, 1963). 15-30 DEG. C AT 16-8 HOURS (USDA, 1952--ANDERSEN, 1941). 10-30 DEG. C, 15-30 DEG. C AT 16-8 HOURS (SPRAGUE, 1940). ROOM-30 DEG.C, 12-30 DEG. C, 20-30 DEG. C AT 18-6 HOURS (ANDERSEN, 1939)
LIGHT-- LIGHT REQUIRED (AOSA, 1978--USDA, 1952--ANDERSEN, 1941--WALDRON, 1921). BRIEF DAILY ILLUMINANCES OF HIGH INTENSITY ARE MOST PROMOTIVE TO GERMINATION (TOOLE AND BORTHWICK, 1971)
GERMINATIVE ENERGY-- 91 P.C. IN 14 DAYS (SPRAGUE, 1940)
GERMINATIVE CAPACITY-- 75 P.C. (HAFENRICHTER ET AL., 1968). OVER 80 P.C. (WHEELER AND HILL, 1957). 80 P.C. (STEFFERUD, 1948). 94 P.C. IN 28 DAYS (SPRAGUE, 1940)
COMMENTS-- MOISTEN SUBSTRATUM WITH 0.2 P.C. KNO3 (AOSA, 1978)
CULTURAL PRACTICES
PLANTING DEPTH-- NO DEEPER THAN 1/4 IN. (ROGLER ET AL., 1961). 1/4 IN. (PLUMMER ET AL., 1943). 1/2 IN. (MURPHY AND ARNY, 1939)
EXPOSURE-- FULL SUNLIGHT OR ONLY SLIGHT SHADING ARE PREFERRED (BEARD, 1973). MODERATELY SHADE TOLERANT (HAFENRICHTER ET AL., 1968--FERGUS, 1962)
SOIL TEXTURE-- ADAPTED TO SANDY, LOAMY (HEADY, 1975). SILTY-GOOD, CLAYEY-GOOD, SANDY-POOR (VALLENTINE, 1971). LOAMS AND HEAVIER TYPES OF SOILS (FERGUS, 1962). MEDIUM TEXTURE (ARCHER AND BUNCH, 1953--WHEELER, 1950). LOAMS OR CLAY LOAMS (USDA, FOR. SER., 1937--STEWART AND WALKER, 1939)
SOIL PH-- 6.0-7.0 (BEARD, 1973). NEARLY NEWTRAL (HAFENRICHTER ET AL., 1968). 5.8-8.2 (WHEELER, 1950)
SOIL MOISTURE-- ADAPTED TO WET (HEADY, 1973). MOIST (BEARD, 1973--ARCHER AND BUNCH, 1953--WHEELER, 1950)
PRECIPITATION-- 20-50 IN. (FERGUS, 1962)
DRAINAGE-- WELL DRAINED (BEARD, 1973--HAFENRICHTER ET AL., 1968--FERGUS, 1962--ARCHER AND BUNCH, 1953--WHEELER, 1950--STEWART AND WALKER, 1939--USDA, FOR. SER., 1937)

GRASSLIKE SORGHASTRUM NUTANS NONE YELLOW INDIANGRASS

A B C

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 9,865-12,530/OZ. 350-440/G (AOSA, 1978). 385,000/KG (HEADY, 1975). 170,000/LB (VALLENTINE, 1971--ATKINS AND SMITH, 1967--COOPER ET AL., 1957). 175,000/LB (WHEELER AND HILL, 1957--STEFFERUD, 1948)
SEED MATURITY-- SEP 1-OCT 30 (ATKINS AND SMITH, 1967). LATE FALL (COOPER ET AL., 1957). SEP-FROST OR EVEN LATER (WHEELER AND HILL, 1957)
METHOD OF COLLECTION-- COMBINE PREFERRED, ALSO BINDER (ATKINS AND SMITH, 1967--COOPER ET AL., 1957). BINDER OR DIRECT COMBINING (HARMOND ET AL., 1961). HARVEST WITH A BINDER OR COMBINE (WHEELER AND HILL, 1957). GRAIN COMBINE (ARCHER AND BUNCH, 1953). COMBINE, BINDER OR TOP WITH A SICKLE (WOLFF, 1951). STRIPPING AND THRESHING (FROLIK AND KEIM, 1938)
METHOD OF CLEANING-- HAMMERMILL RUN AT LOW SPEEDS OR FANNING MILL (WHEELER AND HILL, 1957--WOLFF, 1951)
PRETREATMENT
DURATION OF GOOD VIABILITY-- EXCEEDS 2 YEARS (WHEELER AND HILL, 1957--WOLFF, 1951). 6 YEARS (BLAKE, 1935)
STRATIFICATION-- PRECHILL AT 5 DEG. C FOR 2 WEEKS (AOSA, 1978--USDA, 1952). MOIST CHILLING FOR 4 WEEKS (EMAL AND CONRAD, 1973)
SCARIFICATION-- SOAK SPIKELETS IN CONCENTRATED SULFURIC ACID FOR 10 MINUTES (EMAL AND CONARD, 1973)
LABORATORY GERMINATION
TEMPERATURE-- (B) FLUCTUATING-- 20-30 DEG. C AT 16-8 HOURS (AOSA, 1978--USDA, 1952)
LIGHT-- LIGHT REQUIRED (AOSA, 1978--USDA, 1952). RED LIGHT MORE EFFECTIVE THAN DAY-LIGHT WHEN EXPOSURE TIME IS 2 HOURS OR LESS (EMAL AND CONARD, 1973)
GERMINATIVE ENERGY-- 35 P.C. IN 7 DAYS (WHEELER AND HILL, 1957--WOLFF, 1951)
GERMINATIVE CAPACITY-- 60 P.C. (ATKINS AND SMITH, 1967). 40 P.C. (COOPER ET AL., 1957). 63 P.C. (WHEELER AND HILL, 1957--STEFFERUD, 1948). 62 P.C. (WOLFF, 1951)
COMMENTS-- MOISTEN SUBSTRATUM WITH 0.2 P.C. KNO3 (AOSA, 1978)
CULTURAL PRACTICES
PLANTING DEPTH-- 1/2 IN. (ALLRED AND NIXON, 1955). 1/3-1 IN. (ARCHER AND BUNCH, 1958). MAR-APR (STEFFERUD, 1948)
SOIL TEXTURE-- ADAPTED TO SANDY, LOAMY (HEADY, 1975). SANDY-GOOD, SILTY-GOOD, CLAYEY-FAIR (VALLENTINE, 1971). SAND, SILT OR CLAY (ATKINS AND SMITH, 1955). SANDY LOAM (STEFFERUD, 1948)
SOIL MOISTURE-- ADAPTED TO WET (HEADY, 1975). HIGH MOISTURE REQUIREMENT (COOPER ET AL., 1957). MOIST (FROLIK AND KEIM, 1938)
DRAINAGE-- WELL DRAINED (FROLIK AND KEIM, 1938)
COMMENTS-- (A) GREENHOUSE-- SEEDLINGS PRODUCED EQUALLY WELL WHEN SEEDS ARE PLANTED 1, 2 OR 3 YEARS AFTER HARVEST (ROBOCKER ET AL., 1953)

GRASSLIKE SPOROBOLUS CRYPTANDRUS NONE SAND DROPSEED

CULTURE:
PROCUREMENT
SEEDS/UNIT WT-- 350,005/OZ. 12,345/G (AOSA, 1978). 5,000,000/LB (VALLENTINE, 1971). 5,300,000/LB (WHEELER AND HILL, 1957)

SEED MATURITY-- LATE SUMMER (ARCHER AND BUNCH, 1953)
METHOD OF COLLECTION-- HARVEST WITH A SAMLL GRAIN COMBINE (ARCHER AND BUNCH, 1953--HOOVER ET AL., 1948). POWER STRIPPER (HOOVER, 1939)
METHOD OF CLEANING-- USE GRADUATED SCREENS AND AN AIR BLAST BLOWER (SAYERS, 1968)
PRETREATMENT
DURATION OF GOOD VIABILITY-- 1-5 YEARS (ARCHER AND BUNCH, 1953)
STRATIFICATION-- PRECHILL AT 5 DEG. C FOR 4 WEEKS (AOSA, 1978--USDA, 1952). PRECHILL AT 3 DEG. C FOR 4-8 WEEKS (TOOLE, 1941)
SCARIFICATION-- MAXIMUM PROMOTION OF GERMINATION OBTAINED BY CLIPPING SEEDS WITH A RAZOR BLADE, PRICKING THEM WITH A NEEDLE OR BY TREATING AIR DRY SEEDS IN A FORCED AIR OVEN 35 MINUTES AT 95-100 DEG. C (SAYERS, 1968). 71 P.C. H2SO4 FOR 2 MINUTES (TOOLE, 1941B)
LABORATORY GERMINATION
TEMPERATURE (B) FLUCTUATING-- 5-35 DEG. C, 15-35 DEG. C AT 16-8 HOURS (AOSA, 1978--USDA, 1952). 5-35 DEG. C AT 9-15 HOURS (SAYERS, 1968). 15-25 DEG. C, 20-30 DEG. C (NORRIS AND DECKER, 1944). ROOM TEMPERATURE -35 DEG. C (TOOLE, 1941B)
LIGHT-- LIGHT REQUIRED (AOSA, 1978--USDA, 1952). HIGHER GERMINATION IN LIGHT (SAYERS, 1968)
GERMINATIVE CAPACITY-- 80 P.C. (STEFFERUD, 1948)
COMMENTS-- MOISTEN SUBSTRATUM WITH 0.2 P.C. KNO3 (AOSA, 1978)
CULTURAL PRACTICES
PLANTING DEPTH-- 1/4-1/2 IN. (ALLRED AND NIXON, 1955). 1/2 IN. (STEFFERUD, 1948). LESS THAN 1/2 IN. (FLORY AND MARSHALL, 1942)
PLANTING TIME-- MAR (HYDER ET AL., 1975). MAR-APR (STEFFERUD, 1948)
EXPOSURE-- GROWS BEST IN OPENINGS (PLUMMER ET AL., 1955)
SOIL TEXTURE-- SANDY-GOOD, SILTY-GOOD, CLAYEY-FAIR (VALLENTINE, 1971). SANDY (HAWK AND SCHWENDIMAN, 1962--*USDA, FOR. SER.*, 1937). LOAM TO SAND (ALLRED AND NIXON, 1955). SAND, SANDY LOAM (STEFFERUD, 1948). COMMON ON SANDY SOILS AND ALSO HEAVIER SOILS (FROLIK AND KEIM, 1938)
SOIL MOISTURE-- DRY (FROLIK AND KEIM, 1938)

SHRUB MAHONIA REPENS NONE CREEPING BARBERRY

CULTURE:
PROCUREMENT
SEEDS/LB--54,000-71,000--AVG 62,000 (RUDOLF, 1974A). 71,120 (PLUMMER ET AL., 1968)
SEED MATURITY--JUN-SEP SD (RUDOLF, 1974A). AUG 5-SEP 10 UT (PLUMMER ET AL., 1968)
METHOD OF COLLECTION--HAND PICK OR FLAIL ONTO RECEPTACLES OR CLOTH ON THE GROUND (RUDOLF, 1974A). HAND STRIP INTO HOPPERS (PLUMMER ET AL., 1968)
METHOD OF CLEANING--MACERATE WITH WATER THEN SCREEN OR FLOAT, DRY (RUDOLF, 1974A). DYBVIG WITH WATER, DRY AND FAN (PLUMMER ET AL., 1968)
PRETREATMENT
METHOD OF STORAGE--SEALED CONTAINERS SLIGHTLY ABOVE FREEZING (RUDOLF, 1974A)
DURATION OF GOOD VIABILITY--5 YEARS (RUDOLF, 1974A--PLUMMER ET AL., 1968)
STRATIFICATION AND SCARIFICATION--SUCCESSIVE COLD, WARM, AND COLD STRATIFICATION PERIODS AID GERMINATION (RUDOLF, 1974A). MOIST CHILL AT 2 DEG. C FOR 16 WEEKS IN AN 0.001 MOLAR SOLUTION OF GIBBERELLIC ACID (MCDONOUGH, 1969). MOIST CHILL AT 1 DEG. C FOR 30 DAYS THEN WARM AT 20 DEG. C FOR 60 DAYS THEN MOIST CHILL AT 1 DEG. C FOR 196 DAYS, SCARIFICATION NOT NECESSARY (MCLEAN, 1967)

LABORATORY GERMINATION
TEMPERATURE--CONSTANT AT 34 DEG. F OR 70 DEG. F (RUDOLF, 1974A), CONSTANT AT 2 DEG. C (MCDONOUGH, 1969)
MOISTURE--WET (RUDOLF, 1974A)
GERMINATIVE ENERGY--62 P.C. IN 150 DAYS AT 34 DEG. F (RUDOLF, 1974A)
GERMINATIVE CAPACITY--74 P.C. IN 196 DAYS AT 34 DEG. F OR 10 DAYS AT 70 DEG. F (RUDOLF, 1974A), 79 P.C. IN 28 DAYS (MCDONOUGH, 1969), 74 P.C. (MCLEAN, 1967)
CULTURAL PRACTICES
PLANTING TIME--FALL (RUDOLF, 1974A)
EXPOSURE--SUN, PARTIAL SHADE, OR SHADE (SUTTON AND JOHNSON, 1974)
SOIL TEXTURE--COARSE TO MEDIUM, LOAM (STARK, 1966)
SOIL PH--5.5-7.0 (SUTTON AND JOHNSON, 1974)
SOIL DEPTH--SHALLOW TO MODERATE (SUTTON AND JOHNSON, 1974)
SOIL MOISTURE--DRY TO MOIST (SUTTON AND JOHNSON, 1974)
ORGANIC MATTER--NO (SUTTON AND JOHNSON, 1974)
DRAINAGE--WELL-DRAINED (SUTTON AND JOHNSON, 1974)
NURSERY PLANTING--COVER WITH 1/8-1/2 IN. SOIL AND 1/4 IN. SAND (RUDOLF, 1974A)
FIELD PLANTING--MULCH IMPROVES GERMINATION, MOLD MAY ATTACK SEED PLANTED WITH BERRIES, UNDER NATURAL CONDITIONS SEEDS GERMINATE THE SPRING FOLLOWING DISPERSAL (RUDOLF, 1974A)

SHRUB POTENTILLA FRUTICOSA NONE BUSH CINQUEFOIL

CULTURE:
CULTURAL PRACTICES
EXPOSURE--SEMI-SHADE (STARK, 1966)
SOIL TEXTURE--MEDIUM (STARK, 1966)
SOIL DEPTH--DEEP (STARK, 1966)
SOIL MOISTURE--MOIST (STARK, 1966)
SOIL DRAINAGE--WELL-DRAINED (STARK, 1966)
FIELD PLANTING--MAY BE DIFFICULT TO ESTABLISH FROM SEED (STARK, 1966)

TREE PINUS PONDEROSA NONE PONDEROSA PINE

CULTURE:UNKNOWN

NO. OF ITEMS IN QUERY RESPONSE = 20
NO. OF ITEMS IN THE DATA BANK = 4884
PERCENTAGE OF RESPONSE/TOTAL DATA BANK = .410

END*

APPENDIX D:

REFERENCES FOR REPORTS ON MILITARY TRAINING AREAS

This appendix lists annotated references which contain information useful for monitoring and maintaining military training areas. These publications include vehicle impact studies conducted on military training areas, maintenance techniques, environmental baseline descriptions, biotic surveys, and other useful guidance for land managers who are responsible for training area maintenance.

Baran, R. S., W. D. Severinghaus, D. J. Hunt, and H. E. Balbach, Overview of Considerations in Assessing the Biomass Potential of Army Installations, Technical Report N-108/ADA107132 (CERL, August 1981).

This report provides Army planners with an overview of what must be considered when evaluating the feasibility of using forest resources (biomass) as an alternative source of fuel. It identifies state-of-the-art land management techniques needed for biomass harvest and management and provides a comprehensive annotated bibliography on biomass materials. The report focuses on: (1) procedures for evaluating biomass availability, (2) techniques of harvesting biomass, (3) the feasibility of military development of energy plantations, (4) the economic feasibility of using biomass, (5) managerial and legal constraints, and (6) ecological and silvicultural implications of biomass use.

Canessa, William, "Chemical Retardants Control Fugitive Dust Problems," Pollution Engineering, Vol 9, No. 7 (1977), pp 24-26.

Dust control has become a precise science based on numerous variables. The kind of dust, how it is generated, and the type of control treatment must be taken into account in the planning of a dust control program.

This article discusses the basics of soil movement and a method which arrests soil movement and therefore controls dust. The use of resinous adhesive dust retardants for soil treatment is described. Case histories of using this method are also provided.

Culpepper, M. M., Emplacement and Maintenance of Dust-Control Materials, Instruction Report S-72-3 (Waterways Experiment Station [WES], September 1972).

Army engineer units or groups of indigenous personnel working under Army engineer supervision will use dust-control material(s) to improve existing assault-type airfields and helipads or to construct new ones where required. This report provides guidance for troops who will emplace and maintain dust-control material(s) in conjunction with these duties. It contains information about techniques and construction procedures used successfully during the engineering design tests of the dust-control materials.

Defense Audit Service, Report on the Review of the DOD Forestry Program, Report No. 80-085, April 1980.

The House of Representatives Committee Report on the 1979 Defense Appropriations Bill questioned whether DOD's forestry management program conformed with the most efficient currently accepted forestry practices. A review of DOD forestry management policies and practices in the continental United States was made to determine if better forestry management practices could increase productivity and net profits. Appropriate consideration was given to the military missions of defense installations and to the requirements for preserving wildlife habitat. Personnel and equipment assigned to the program were reviewed; DOD management and sales practices were then compared with those of other Government agencies having large tracts of woodlands.

Goran, W. D., Radke, L. L., and Severinghaus, W. D., An Overview of the Ecological Effects of Tracked Vehicles on Major U.S. Army Installations, Technical Report N-140 (CERL, 1983).

Quantitative and qualitative field studies were done at 12 Army installations to provide a general overview of the ecological impacts resulting from U.S. Army tactical vehicle training. The effects on mammal, bird, and plant populations were monitored, and damage to soils was examined. A loss in biomass and a change in species composition were noted. An increase in soil erosion and compaction was also observed.

Green, A. J., D. D. Randolph, and A. A. Rula, The Effect of Military Transportation Activities on the Environment, Misc. Paper M-73-15 (WES, 1973).

This study evaluates the impact of military transportation activities on related environmental attributes. A matrix was then used to relate the activities to their impacts. This matrix used a scale to identify the magnitude and probability of the impact. Known mitigation and abatement practices that can be used to minimize adverse environmental impacts were also identified and described briefly. The principal conclusion was that this matrix technique provided a good first approximation for assessing the effect of military transportation on the environment.

Keown, M. P. and H. W. West, Environmental Baseline Descriptions for Use in the Management of Fort Carson National Resources, Report, Analysis, and Assessment of Soil Erosion in Selected Watersheds, TR M-77-4 (WES, 1978).

Six watershed study areas at Fort Carson, each having a sediment catchment basin, were selected for analysis. Borings were made in the catchment basins to determine the accumulated sediment volume. These data were used with the age and area of the basin to estimate the average annual sediment yield for each watershed. A watershed erosion index reflecting the collective influence of rainfall, soil erodibility, topography, and land use was derived based on the Universal Soil-Loss Equation.

The remaining life of the catchment basins was estimated. By correlating average annual sediment yield with the watershed erosion index, soil loss can be evaluated in terms of military training schedules, and the percent of catchment basin sediment volume caused by military activity can be determined. The general procedures for establishing the correlation and using the methodology to assess the impact of military training activities on soil erosion apply to any military reservation having catchment basins. The

methodology can also be used as an engineering design aid for developing new sediment retention structure design parameters.

Rekas, Anthony B., Environmental Baseline Descriptions for Use in the Management of Fort Carson Natural Resources, Report 1, Development and Use of Wildlife and Wildlife Habitat Data, TR M-77-4 (WES, 1977).

This report presents detailed environmental data on wildlife and wildlife habitats at Fort Carson, CO, from 1 August 1975 to 1 March 1977. Narrative accounts on 13 animal species were prepared from the wildlife literature and from information obtained from State and Federal wildlife biologists. Information is provided on the habits and habitat requirements of the mule deer, pronghorn, black-tailed prairie dog, scaled quail, bobcat, mountain lion, coyote, golden eagle, mourning dove, cottontail rabbit, Abert's squirrel, black bear, and the black-footed ferret.

A conceptual habitat identification and mapping procedure is described. By mapping black-tailed prairie dog habitat, it was shown that 70,000 acres of Fort Carson (52 percent) were potential prairie dog habitats. Forty of forty-three existing and abandoned prairie dog towns studied were identified within designated potential habitat areas.

Rostler, F. S., and W. M. Kuntel, Jr., "Soil Stabilization," Industrial and Engineering Chemistry (American Chemical Society, April 1964), pp 27-33.

This article describes efforts aimed at developing new methods of soil stabilization. A product called Coherex was tested on sites requiring erosion control. Edwards Air Force Base in the Mojave Desert and Vandenberg Air Force Base in the coastal dune area were among the study sites treated. The purpose of the testing was to determine the action of various resinous fractions on soils; this included testing the product's effect on cohesiveness, resistance to erosion and traffic, and effect on soil fertility, porosity, and other agronomic requirements.

Schanche, G. W., and M. J. Savoie, Fort Carson Fugitive Dust Generation and Transport Study: Lessons Learned, Technical Report N-117/ADA110330 (CERL, November 1981).

The State of Colorado considered Fort Carson and its training and combat readiness activities major contributors to the noncompliant Total Suspended Particulate (TSP) levels of the San Isabel Air Quality Control Region. This study was performed to determine Fort Carson's effect on the TSP levels in the communities surrounding the installation, to identify and quantify significant TSP-producing activities on Fort Carson, and to recommend measures to control TSP.

The study indicated that Fort Carson has a highly localized TSP problem in areas next to unpaved roads and parking/staging areas, and in heavily used artillery firing ranges. To control TSP, the report recommends various techniques of dust suppression, as well as changes in the scheduling of training exercises and the movement of convoys.

Severinghaus, W. D., W. D. Goran, G. D. Schnell, and F. L. Johnson, Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX, Technical Report N-113/ADA109646 (CERL, September 1981).

A field study was conducted at Fort Hood, TX, to investigate the effects of Army tracked vehicle training on the resident mammal, bird, and plant populations. Indications of ecological differences between selected areas used for vehicle training and areas undisturbed by training are described. Fort Hood's ecosystem is analyzed to verify the effects of training activities on ecosystems examined in previous research.

Severinghaus, W. D., and W. D. Goran, Effects of Tracked Vehicle Activity on Mammals, Birds, and Vegetation at Fort Lewis, WA, Technical Report N-116/ADA111201 (CERL, November 1981).

A field study was conducted at Fort Lewis, WA, to investigate the effects of Army tracked vehicle training on the resident mammal, bird, and plant populations. Indications of ecological differences between selected areas used for vehicle training and areas undisturbed by training are described. Fort Lewis' ecosystem is analyzed to verify the effects of training activities on ecosystems examined in previous research.

Severinghaus, W. D., and W. D. Goran, "Notes on the Distribution and Ecology of Some Birds and Mammals in Central Texas," Texas Journal of Science (in press).

This article discusses several points regarding the known ranges of mammals and birds in central Texas; the data presented is based on studies conducted at Fort Hood, TX. Included is a list of species observed that had not been previously recorded in the scientific literature as being found in that region.

Severinghaus, W. D., R. E. Riggins, and W. D. Goran, "Effects of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, KY," Transactions of the Kentucky Academy of Science, Vol 41, No. 1-2 (1980), pp 15-26.

A field study was conducted at Fort Knox, KY, to investigate the effects of Army tracked vehicle training on terrestrial birds and mammals. Intensive studies were conducted at three sites representative of a long-term training area, a short-term training area, and a control area. This report provides preliminary indications of ecological differences between Army tracked vehicle training areas and areas representing pre-training (no training) conditions. Principal changes were caused by clearing and compacting the soil, vegetational disturbance, and resultant erosion in the training areas.

Severinghaus, W. D., R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Technical Report N-77/ADA073782 (CERL, July 1979).

A field study was conducted at Fort Knox to investigate the effects of Army tracked vehicle training on terrestrial birds, mammals, and vegetation. Intensive studies were conducted at three sites representative of a long-term training area, a short-term training area, and a control area. Indications of

ecological differences between tracked vehicle training areas and areas undisturbed by training are described.

Severinghaus, W. D., and M. C. Severinghaus, "Effects of Tracked Vehicle Activity on Bird Populations," Environmental Management, Vol 6, No. 2 (1982), pp 163-169.

This study developed cause and effect relationships between Army training activities and bird populations throughout the continental United States. Installations in Kentucky, Louisiana, Texas, and Washington were selected as representative of diverse ecosystems and extent of Army training. Birds were separated into 31 guilds for analyzing the different ecosystems. The results showed that: (1) guild theory can be useful for analyzing impacts within and between ecosystems; (2) tracked vehicles disturb bird populations because of habitat alteration and reduction; (3) the change in biomass ranged from 20.9 to -55.3 percent and depends on the extent of training and ecosystem type; and (4) species replacement should be a major concern.

Styron, C. R., III, Erosion Control at the Area Facility, Kirtland Air Force Base, New Mexico, Misc. Paper S-72-27 (WES, June 1972).

This report describes application of a dust control system (DCA-1295 reinforced with fiberglass) for erosion control. A soil sterilant was used before the system was applied after it was ascertained that the sterilant would be compatible with the dust control materials. A soil sterilant was necessary because tumbleweed -- the most common type of vegetation in this area -- does not control erosion effectively. Vegetative growth occurring after the dust control material had been placed would have destroyed the system.

The results of this investigation produced the following conclusions:

1. The soil sterilant used is compatible with fiberglass and DCA-1295.

2. Use of this stabilization system at the specified design rates will control erosion.

3. Chopped grass is easier to apply on steep slopes than the scrim, mainly because of the weight of the packages (30 versus 230 lb [12 versus 92 kg]).

4. Cutter guns are unsuitable for large projects; however, they are ideal for special jobs where small areas can be covered in a reasonable time.

Styron, C. R., III, and R. C. Eaves, Investigation of Dust-Control Materials, Misc. Paper S-73-70 (WES, December 1973).

This report describes a program which tried to find a material that would control dust during military operations in the Southeast Asia theater of operations. Dust seriously reduced the life expectancy of machinery, increased the time required for refueling and other services, increased logistics problems, seriously lowered the morale of troops, and sometimes showed the enemy locations of operations.

WES compiled a list of essential and desirable characteristics for a dust control agent; these were used as guidelines before a Qualitative Materiel Requirement for Dust-Control Materiel was issued on 1 August 1966 (revised 10 May 1971). A screening procedure was set up in which a series of tests could be used to readily determine a material's potential based on how it compared with other products tested. Successful products were processed through a laboratory investigation, a traffic test, a downwash blast test, a weathering cycle test, and finally a field test.

U.S. Department of the Army, Granting Use of Real Estate, Army Regulation 405-80 (1979).

This regulation sets forth the authority, policy, responsibility, and procedure for making Army real estate available to other military departments, Federal agencies, State and local government agencies, and private organizations or individuals. It outlines authorizations and restrictions on a lessee performing maintenance in lieu of paying a rental fee.

U.S. Department of the Army, Natural Resources -- Land, Forest, and Wildlife Management, Army Regulation 420-74 (1977).

This regulation sets forth policies, procedures, and responsibilities for conserving, managing, and restoring land and its renewable natural resources, consistent with the military mission and national policies. This includes the conservation, management, and use of the soils, water areas, croplands, rangelands, forests, and fish and wildlife species on Army installations.

U.S. Department of the Army, Natural Resources -- Land, Forest, and Wildlife Management, DA Pamphlet 420-7 (1977).

This pamphlet provides information and guidance to commanders for managing installation land and water areas, including applicable forest and fish and wildlife resources. It provides details and procedures and suggests materials for implementing the policies and responsibilities prescribed by AR 420-74.

U.S. Department of the Army, Planting and Establishment of Trees, Shrubs, Ground Covers, and Vines, Technical Manual 5-830-4 (June 1976).

This manual provides guidelines and prescribes standard techniques to be used in planting and the initial care required to successfully establish trees, shrubs, ground covers, and vines. Criteria for selecting materials are described, and each step needed to achieve the desired objectives of a planting plan is described.

Also described are the various ways plants are grown for transplanting, how they should be prepared for moving, how they should be planted, and procedures to follow while the plants become adapted to their new location. The planting of trees, shrubs, ground covers, and vines should comply with approved landscape planting plans and should be based on the master plan for future installation development.

U.S. Department of the Army, Planting Turf, Technical Manual 5-830-2 (1961).

This manual discusses the factors affecting turf establishment: climate, soils, and management. It outlines treatment of areas before and after planting, selection of seed and seed mixtures, and planting methods. Information on common plant species is also provided.

U.S. Department of the Army, Repair and Utilities, Ground Maintenance and Land Management, Technical Manual 5-630 (1967/1982).

This manual provides information useful to personnel engaged in grounds maintenance and land management at Army installations. The emphasis is on maintenance of improved grounds, such as parade grounds and golf courses. The manual prescribes principles and practices for land management, soil analysis and improvement, the growing and maintenance of turf, and landscape planting and maintenance. It explains how soil, climate, and choice of plants affect vegetation growth. It prescibes measures for erosion control, weed and brush control, drainage, and fire protection. A model checklist for preventive maintenance operations is also included. Properly applied, the prescribed principles and practices will conserve the natural resources of Army lands, maintain and improve the appearance of grounds, and promote operational safety and efficiency.

U.S. Department of the Army, Soils, Drainage, and Planting for Emergency Construction -- Dust Control, Emergency Construction, Technical Manual 5-886-7 (1964).

This manual prescribes the standards of emergency construction for dust and wind erosion control on an installation's unpaved soil areas. It describes factors affecting the selection of dust control measures and provides procedures to be used until permanent control methods are begun.

U.S. Department of the Army, Soils, Drainage, and Planting for Emergency Construction -- Establishing Turf, Emergency Construction, Technical Manual 5-886-6 (1965).

This manual provides the standards of emergency construction to be used for establishing of turf. Soil characteristics and climatic conditions are discussed in terms of their suitability for turf plantings. Guidance on seedbed preparation, selection of plant species and seed type, and planting methods is provided.

U.S. Department of Transportation, Federal Highway Administration, Special Product Evaluation List, Technical Report RD-80/127, December 1979.

This document is a listing of special products which have been evaluated by State highway or transportation departments. The categories described are chemical products, manufacturers, description and use of the products, the states where they were tested, and additional remarks. Of particular interest are the sections on mulch and erosion controls, soil sterilization and weed control materials, and soil treatments used for erosion control.

U.S. General Accounting Office, DOD Can Increase Revenues Through Better Use of Natural Resources It Holds in Trust, Document No. PLRD-82-9 (November 1981).

DOD policy requires all military bases to manage their lands, which contain vast natural resources, under the multi-use principle, consistent with the military mission. Multiple uses include forestry, agricultural leasing, fish and wildlife programs, and recreation.

This report discusses how DOD can improve its natural resources program and gain more than $3 million in revenues annually by the following: greater emphasis on planning for the effective use of land and natural resources; innovative planning and administration to increase forest productivity; increased efforts to identify and lease land for agriculture; greater emphasis on providing opportunities for public outdoor recreation on military bases; and assessing of more equitable user fees for hunting and fishing on military lands to finance fish and wildlife programs.

Witco Chemical, "How Holloman Air Force Base Uses Dust Control For Safety," Grounds Maintenance (Intertec Publishing Corporation, May 1968).

A dust control program was started at Holloman Air Force Base, NM, to give pilots optimum visibility conditions. In 1967, Coherex was used to treat about 207 acres at this base. The procedure for application is described.

APPENDIX E:

EQUIPMENT INFORMATION

Equipment Development Center

The Forest Service's Equipment Development Center was originally associated with fire control activity and related equipment. It has since become the center for developing equipment for all aspects of Forest Service work, including revegetation. Each of the nine Forest Service regions suggests needs and priorities within its region. From these suggestions, a list of equipment needs is developed according to national priorities. The Equipment Development Center then begins developing the required equipment.

Equipment is often developed completely at the Center. If a commercial company produces equipment similar to what is needed, the Center works with the manufacturer to modify the equipment for the desired purpose. The two Equipment Development Centers are located at:

USDA Forest Service
Equipment Development Center
444 East Bonita Ave.
San Dimas, CA 91773
(714) 599-1267 or (213) 332-6231
FTS 793-8000

USDA Forest Service
Equipment Development Center
Bldg 1, Fort Missoula
Missoula, MT 59801
(406) 549-3157 FTS 585-3157

Vegetative Rehabilitation and Equipment Workshop (VREW)

VREW is an organization of Federal and State agencies and private groups which work together to improve rangelands and develop rangeland equipment technology. VREW evaluates and develops equipment and prescribes specifications and standards for equipment purchase, maintenance, and use. The workshop is also a clearinghouse for exchanging of information and disseminating of material describing its activities.

VREW is held each year several days before the annual meeting of the Society of Range Management. For information, contact:

Dan McKenzie
Equipment Development Center
USDA Forest Service
444 E. Bonita Ave.
San Dimas, CA 91773

or

Ted V. Russell
Range Management Staff
USDA Forest Service
P.O. Box 2417
Washington, DC 20013

To obtain information on equipment or techniques, contact the appropriate work group chairman:*

Steering Committee:

Ted V. Russell, Chairman, FS
P.O. Box 2417
Washington, DC 20013

Exploratory Committee:

Ted V. Russell, Chairman, FS
P.O. Box 2417
Washington, DC 20013

Information Committee:

Ray Dalen, Chairman, FS
517 Gold Ave. SW
Albuquerque, NM 87102

* Current as of 1980.

Seeding and Planting Committee:

Ross J. Wight, Chairman, SEA
Northern Great Plains
Research Center
Box 1109
Sidney, MT 59270

Arid Land Seeding Committee:

Carlton H. Herbel, Chairman, SEA
Jornada Experimental Range
P.O. Box 698
Las Cruces, NM 88001

Plant Materials Committee:

Gil Lovell, Chairman, SCS
National Plant Materials Center
BARC-East, Bldg. 509
Beltsville, MD 20705

Seed Harvesting Committee:

A. Perry Plummer, Chairman, FS
Shrub Sciences Laboratory
735 North 500 East
Provo, UT 84601

Steep-Slope Stabilization Committee:

Lou Spink, Chairman, FS
Division of Range
Box 3623
Portland, OR 97208

Disturbed Land Reclamation Committee:

Ron Younger, Co-Chairman, BLM
Utah State Office
136 East South Temple
Salt Lake City, UT 84111

Willis Vogel, Co-Chairman, FS
Berea, KY

Thermal Plant Control Committee:

Bill Davis, Chairman, FS
Federal Bldg.
324 25th St.
Ogden, UT 84401

Mechanical Plant Control Committee:

Loren Brazell, Chairman, BLM
300 Booth St.
Reno, NV 89509

Chemical Plant Control Committee:

Ray Dalen, Chairman, FS
517 Gold Ave. SW
Albuquerque, NM 87102

Structural Range Improvements Committee:

Ron Haag, Chairman FS
Range Management
Region 1, Federal Bldg.
Missoula, MT 59807

The following are specifications and available information from VREW on selected planting equipment used for controlling plants, ground preparation, fertilizing and mulching, and seed bed preparation. All information is from the Equipment Development Center's Revegetation Equipment Catalog (February 1980).

Fixed Wing Aircraft-Venturi-type Spreader

Specifications:

Swath width: 18 to 50 ft (5.5 to 15.2 m)
Payload capacity: 150 to 400 gal (568 to 1514 L)
260 to 10,800 lb (118 to 4900 kg)
Power ratings: 150 to 2100 hp (112 to 1566 kW)

Availability:

Contractors:

Aerial application contractors operate from many local airports.

Equipment:

Simplex Manufacturing Co.
5224 Northeast 42nd Ave.
Portland, OR 97218
(503) 281-0039

Transland, Inc.
24511 Frampton Ave.
Harbor City, CA 90710
(213) 534-2511

Helicopter Spreaders

Specifications:

Swath width: 25 to 200 ft (7.6 to 61 m)
Payload capacity: 20 to 80 cu ft (566 to 2265 L)
210 to 2200 lb (80 to 1000 kg)
Power ratings: 180 to 1700 hp (139 to 1268 kW)

Availability:

Contractors:

Aerial application contractors operate from many local airports.

Rotary Spreaders:

Campbell Air Services, Inc.
Box 872
Vivian, LA 71082
(318) 375-3207

Chadwick, Inc.
11969 Southwest Herman Rd.
Sherwood, OR 97140
(503) 638-8511

Evergreen Helicopters
Three Mile Lane
McMinnville, OR 97128
(503) 472-4151

Rambling Rotors, Inc.
Rt. 2, Box 2744
LaGrande, OR 97850
(503) 963-5644

Simplex Manufacturing Co.
5224 Northeast 42nd Ave.
Portland, OR 97218
(503) 281-0039

Transland, Inc.
24511 Frampton Ave.
Harbor City, CA 90710
(213) 534-2511

Hydraulic Seeding System:

AmChem Products, Inc.
Brookside Dr.
Ambler, PA 19002
(215) 628-1000

Blower Spreader:

Simplex Manufacturing Co.
5224 Northeast 42nd Ave.
Portland, OR 97218
(503) 281-0039

Seed Dribblers

Specifications

Hopper capacity: 740 to 925 cu in (12 to 15 L)
Seed dribblers are easily mounted on most crawler tractors.

Availability:

Laird Welding and Manufacturing Works
Box 1053
531 South Highway 59
Merced, CA 95340
(209) 722-4145

Stanley G. Mitchell
Box 241
Fredonia, AZ 86022
(602) 643-2750

Blower Spreader

Specifications:

Pattern width: 12 ft (3.7 m)
Hopper capacity: 1.9 to 2.2 cu ft (53 to 62 L)
Power supply: 12- or 24-v (dc) electrical system

Availability:

Holt Machinery Co.
Box 658
San Antonio, TX 78293
(512) 648-1111

Hydraulic Seeder-Mulcher (Hydroseeder)

Specifications:

Spray range: 20 to 200 ft (6.1 to 61 m)
360° horizontal rotation
120° to 160° vertical travel
Tank capacity: 150 to 3000 gal (568 to 11,355 L)
Pump capacity: 70 to 950 gal per min (265 to 3596 L/min)
Power ratings: 8 to 151 hp (6 to 113 kW)

Availability:

Bowie Industries
Box 931
Bowie, TX 76230
(817) 872-2286

Reinco
Box 584
Plainfield, NJ 07061
(201) 755-0921

Finn Equipment Co.
2525 Duck Creek Rd.
Cincinnati, OH 45208
(513) 871-2529

Pasture Drills

Specifications:

Drills with double-disk openers:
Overall width: 6 ft, 8 in. to 16 ft, 4 in. (2 to 5 m)
Working width: 6 ft to 13 ft, 2 in. (1.8 to 4 m)
Row spacing: 6 to 8 in. (15 to 20 cm)
Hopper capacity: 13 to 45 cu ft (350 to 1270 L)

Power requirements (drawbar):
30 hp (22 kW) single
45 hp (34 kW) dual

Drills with flexible runner or chisel type openers:
Overall width 6 ft, 8 in. to 23 ft, 8 in. (2 to 7.2 m)
Working width 6 ft to 19 ft, 5 in. (1.8 to 5.9 m)
Row spacing: 7 in. (18 cm)
Hopper capacity: 13 to 32 cu ft (350 to 900 L)
Power requirements (drawbar):
30 hp (22 kW) single
45 hp (34 kW) dual

Availability:

Drills with double-disk openers:

P&D Duncan, Ltd.
Box 124
Christchurch, New Zealand

Haybuster Manufacturing Co.
Box 1008
Jamestown, ND 58401
(701) 752-4601

Melroe Division Ag. Products
Clark Equipment Co.
Box 1215
Bismarck, ND 58501
(701) 222-5000

Midland Manufacturing Co.
Electric Mills, MS 39320
(601) 476-3061

Miller Seed Co.
Box 81823
Lincoln, NE 68501
(402) 432-1232

Truax Co.
3717 Vera Cruz Ave.
Minneapolis, MN 55422
(612) 537-6639

The Tye Co.
Box 218
Lockney, TX 79241
(806) 852-3597

Drills With Flexing Runner or Chisel-Type Openers:

Aitchison Industries, Ltd.
Box 27
Wanganui, New Zealand

Australian Farm Equipment Pty., Ltd.
1818 Westlake Ave. North
Seattle, WA 98109
(206) 284-9236

Horwood Bagshaw, Ltd.
Box 270
Clarence Gardens, South Australia, 5039
Australia

Napier Grasslands Pty., Ltd.
Box 244
Taree, NSW, 2430
Australia

The Tye Co.
Box 218
Lockney, TX 79241
(806) 852-3597

Information may be obtained from:

Texas Agricultural Experiment Station
Texas A&M University
Box 1658
Vernon, TX 76384
(817) 552-9941

Grass Seeder

Specifications:

Width: 5 to 12 ft (1.5 to 3.7 m)
Roller diameter: 12 in. (30 cm) front
9 in. (23 cm) rear
Hopper capacity: .9 to 6.5 cu ft (26 to 185 L) front
1.6 to 6.5 cu ft (44 to 185 L) rear
Power requirements (drawbar): 40 hp (30 kW)

Availability:

Brillion Iron Works
200 Park Ave.
Brillion, WI 54110
(414) 756-2121

Grain Drills

Specifications:

Width: 6 ft, 8 in. to 26 ft, 8 in. (2 to 8.1 m)
Row spacing: 6 to 18 in. (15 to 46 cm)
Hopper capacity: 13 to 56 cu ft (350 to 1570 L)
Power requirements (drawbar):
20 to 25 hp (15 kW) single
30 hp (22 kW) dual or triple

Availability:

Grain drills are available from many farm implement manufacturers and farm equipment dealers.

Rangeland Drill

Specifications:

Overall width:
8 ft, 6 in. (2.6 m) half size
13 ft, 6 in. (4.1 m) full size
Working width:
5 ft (1.5 m) half size
10 ft (3 m) full size
Row spacing: 12 or 18 in. (30 to 46 cm)
Hopper capacity: 13 to 36 cu ft (460 to 1030 L)
Power requirements (drawbar):
40 hp (30 kW) minimum
45 hp (34 kW) recommended
65 hp (48 kW) dual
90 hp (67 kW) triple

Availability:

Laird Welding and Manufacturing Works
Box 1053
531 South Highway 59
Merced, CA 95340
(209) 268-8128

Drawings (RM27-01-61), Service & Parts Manual, & Operations Handbook available from:

USDA Forest Service
Equipment Development Center
444 East Bonita Ave.
San Dimas, CA 91773
(714) 599-1267 or (213) 332-6231
FTS 793-8000

Oregon Press Seeder

Specifications:

Width: 13 ft (4 m)
Furrow spacing: 12 in. (30 cm)
Hopper capacity: 31 to 43 cu ft (850 to 1200 L)
Power requirements (flywheel): 42 to 72 hp (31 to 54 kW)

Availability:

Drawings (RM 19-01 to 07) and information can be obtained from:

USDA Forest Service
Equipment Development Center
444 East Bonita Ave.
San Dimas, CA 91773
(714) 599-1267 or (213) 332-6231
FTS 793-8000

Range Interseeder

Specifications:

Furrow width: 8 to 32 in. (20 to 81 cm)
Furrow depth: 1.5 to 4.7 in. (3.8 to 12 cm)
Row spacing: 3 to 6.5 ft (.9 to 2 m)
Hopper capacity: to 1.6 cu ft (45 L)
Power requirements: 20 hp (14 kW) minimum

Availability:

Miller Seed Co.
Box 81823
Lincoln, NE 68501
(402) 432-1232

R. A. Whitfield Manufacturing Co.
6431 Gordon Circle SW
Mableton, GA 30059
(404) 948-1212

Information may be obtained from:

USDA Forest Service
Equipment Development Center
444 East Bonita Ave.
San Dimas, CA 91773
(714) 599-1267 or (213) 332-6231
FTS 793-8000

Interseeder for Rocky and Brushy Areas

Specifications:

Width: 14 to 36 in. (36 to 91 cm)
Depth: to 8 in. (20 cm)
Hopper capacity: 925 cu in. (15 L)
Power ratings: 42 hp (31 kW)

Availability:

Drawings and information can be obtained from:

USDA Forest Service
Equipment Development Center
San Dimas, CA 91773
(714) 599-1267 or (213) 332-6231
FTS 793-8000

Tree Spade

Specifications:

Three-Blade:

Ball (cone) diameter: 30 in. (76 cm)
Ball (cone) depth: 16 in. (41 cm)
Tree size*: to 3 in. (8 cm) diameter
Mounting: rear-wheel drive tractors or small front-end loaders

Four-Blade:

Ball (cone) diameter: 20 to 78 in. (51 to 198 cm)
Ball (cone) depth: 18 to 60 in. (46 to 152 cm)
Tree size*: to 10 in. (25 cm) diameter
Mounting: tractors, trailers, truck, or front-end loaders

Availability:

Three-Blade:

Arrowhead Creative Products
6340 Rice Lake Rd.
Duluth, MN 55803
(218) 724-1945

*Maximum tree size may vary with the type of root structure.

Caretree Systems
Box 347
Worthington, OH 43229
(614) 846-2665

Melroe Div.
Clark Equipment Co.
112 North University Dr.
Fargo, ND 58102
(701) 293-3220

Four-Blade:

Big John Tree Transplanter Mfg. Co., Inc.
Box 608
Heber Springs, AK 72543
(501) 362-8161

Vermeer Manufacturing Co.
Box 200
Pella, IA 50219
(515) 628-3141

Vegetative Control

Root Plows

Specifications:

Draft models:
Cutting width: 7 ft, 2 in. to 16 ft, 2 in. (2.2 to 4.9 m)
Depth: to 36 in. (91 cm)
Power requirements (flywheel): 105 to 370 hp (78 to 276 kW)

Toolbar models:
Cutting width: 3 ft to 7 ft, 6 in. (.9 to 2.3 m)
Depth: to 16 in. (41 cm)
Power requirements (flywheel): 60 to 172 hp (45 to 128 kW)

Availability:

Draft Models:

Flexo Corp.
Box 2370
Jacksonville, FL 32203
(904) 354-8361

Holt Machinery Co.
Box 658
San Antonio, TX 78293
(512) 648-1111

Rockland Manufacturing Co.
Box 5
Bedford, PA 15522
(814) 623-1115

Rome Industries
Box 48
Cedartown, GA 30125
(404) 748-4450

Toolbar models:

Holt Machinery Co.
Box 658
San Antonio, TX 78293
(512) 648-1111

Rome Industries
Box 48
Cedartown, GA 30125
(404) 748-4450

Rails

Specifications:

A-rail:
Width: 16.5 ft (5 m)
Power requirements (flywheel): 37 to 60 hp (28 to 45 kW)

Supp rail:
Width: 33 ft (10 m)
Power requirements (flywheel): 37 to 60 hp (28 to 45 kW)

Rail drag:
Width: 33 ft (10 m)
Power requirements (flywheel): 42 to 72 hp (31 to 54 kW)

Availability:

Rails can be manufactured at local machine shops. New materials and sturdy welds should be specified because used rails and unsound welds are major causes of breakage.

Information may be obtained from:

USDA Forest Service
Equipment Development Center
444 East Bonita Ave.
San Dimas, CA 91773
(714) 599-1267 or (213) 332-6231
FTS 793-8000

Chaining

Specifications:

Two-tractor operation:
Length: 90 to 300 ft (27.5 to 91.4 m)
Weight*: 60 to 90 lb/ft (90 to 135 kg/m)
Power requirements (flywheel):
172 hp (128 kW) minimum
190 to 290 hp (142 to 216 kW) recommended

5 ft (1.5 m) diameter ball and chain:
Length: 60 to 180 ft (18.3 to 48.9 m)
Weight*: 20 to 60 lb/ft (30 to 90 kg/m)
Power requirements (flywheel):
172 hp (128 kW) minimum
260 tp 290 hp (194 to 216 kW) recommended

Availability:

Anchor chains, connector links, and steel balls (marine buoys) are available from Navy surplus outlets. Chains can be modified at most local machine shops.

Cables are available from suppliers of construction or logging equipment.

Drawings (No. 568) are available from:

USDA Forest Service
Equipment Development Center
Bldg 1, Fort Missoula
Missoula, MT 59801
(406) 329-3157
FTS 585-3157

For additional information refer to:

Cain, D., 1971. The Ely Chain. USDI Bureau of Land Management Handbook. 32 p.

*Excluding modifications.

Disk-chain information may be obtained from:

Texas Agricultural Experiment Station
Texas A&M University
Box 1658
Vernon, TX 76384
(817) 552-9941

Pipe Harrow

Specifications:

Width: 8 to 14 ft (2.4 to 4.3 m)
Pipe length: 10 ft to 11 ft, 5 in. (3 to 3.5 m)
Pipe diameter: 2 to 4 in. (4.1 to 10.2 cm)
Power requirements (flywheel):
42 to 60 hp (31 to 45 kW) single
72 to 105 hp (54 to 78 kW) dual

Availability:

Drawings (RMI-01 and 02) are available from:

USDA Forest Service
Equipment Development Center
444 East Bonita Ave.
San Dimas, CA 91773
(714) 599-1267 or (213) 332-6231
FTS 793-8000

Drawings for the modified design are available from:

USDA Forest Service
Coconino National Forest
Blue Ridge Ranger District
Happy Jack, AZ 86024
(602) 477-2255

Ground Preparation

Subsoilers

Specifications:

Width: 7 ft, 6 in. to 18 ft (2.3 to 5.5 m)
Depth: to 30 in. (76 cm)
Shank spacing: 18 to 40 in. (36 to 102 cm)
Power requirements (drawbar): 55 to 315 hp
(41 to 235 kW)

Availability:

Agristruction, Inc.
41286 Rd. 124
Orosi, CA 93647
(209) 528-4788

Allis Chalmers
Agricultural Equipment Division
Box 512
Milwaukee, WI 53201
(414) 475-2000

Brillion Iron Works
200 Park Ave
Brillion, WI 54110
(414) 756-2121

Bush Hog
Division of Allied Products Corp.
Box 1039
Selma, AL 36701
(205) 872-6261

J. I. Case Co.
700 State St
Racine, WI 53404
(414) 636-6011

Deere and Co.
John Deere Rd
Moline, IL 61265
(309) 752-8000

Dickey Machine Works
Box 5610
Pine Bluff, AK 71601
(501) 536-1300

Forrest City Machine Works
Box 984
Forrest City, AK 72335
(501) 633-1514

Hiniker Co.
Box 3407
Mankato, MN 56001
(507) 625-6621

International Harvester Co.
Agricultural Equipment Division
401 North Michigan Ave
Chicago, IL 60611
(302) 836-3874

Landoll Corp
1700 May St
Marysville, KS 66508
(913) 562-5381

Lubbock Manufacturing Co.
Box 1589
Lubbock, TX 79408
(806) 762-5261

Napier Grasslands Property, Ltd.
Box 244
Taree, NSW, 2430
Australia

Plant Plows, Inc.
Box 3779
Amarillo, TX 79106
(806) 355-9786

United Farm Tools, Inc.
Box 9175
South Charleston, W. VA 25309
(304) 768-8221

Gougers

Specifications:

Implement width: 11 ft (3.4 m)
Depression width: 15 to 22 in. (38 to 56 cm)
Depression length: 3 to 4 ft (.9 to 1.2 m)
Depth: 6 to 10 in. (15 to 25 cm) recommended
Power requirements (drawbar): 50 hp (37 kW) minimum

Availability:

Drawing (No. 583) is available from:

USDA Forest Service
Equipment Development Center
Bldg 1, Fort Missoula
Missoula, MT 59801
(406) 549-3157
FTS 585-3157

Offset Disks

Specifications:

Cutting width: 6 to 32 ft (1.8 to 9.8 m)
Depth: 8 to 16 in. (20 to 91 cm)
Disk diameter: 28 to 50 in. (71 to 127 cm)
Weight: 500 lb per ft (744 kg/m) recommended
Power requirements (drawbar): 60 to 315 hp (45 to 235 kW)

Availability:

AMCO Products
1 AMCO Dr
Yazoo City, MS 39194
(601) 764-4464

Austin Products, Inc.
Athens Plow Div.
Box 609
Athens, TN 37303
(615) 745-3561

J. I. Case Co.
700 State St
Racine, WI 53404
(414) 636-6011

Deere and Co.
John Deere Rd
Moline, IL 61265
(309) 752-8000

International Harvester Co.
Agricultural Equipment Division
401 North Michigan
Chicago, IL 60611
(312) 836-3874

Kewanee Machinery Division
Chromalloy American Corp.
1516 Burlington Ave.
Kewanee, IL 61443
(309) 852-2191

Miller Manufacturing Co.
Box 305
Straton, NE 69043
(308) 276-2131

Napier Grasslands Pty., Ltd.
Box 244
Taree, NSW, 2430
Australia

Rome Industries
Box 48
Cedartown, GA 30125
(404) 748-4450

Towner Manufacturing Co.
Box 6096
Santa Ana, CA 92706
(714) 542-6767

Pitting Disk Plows

Specifications:

Width: 3 ft, 9 in. to 15 ft (1.1 to 4.6 m)
Depth: 4 in. (10 cm)
Power requirements (drawbar): 30 to 215 hp (23 to 160 kW)

Availability:

G. N. Scranton
Box 229
Lamar, CO 81052
(303) 336-5317

Cut-out disks may be fabricated
at most machine shops.

Basin Blade

Specifications:

Width: 10 ft (3 m)
Depth: to 36 in. (91 cm)
Power requirements (flywheel): 290 to 370 hp
(216 to 276 kW)

Availability:

Drawings (No. 619) are available from:

USDA Forest Service
Equipment Development Center
Bldg. 1, Fort Missoula
Missoula, MT 59801
(406) 549-3157
FTS 585-3163

Contour Furrower

Specifications:

Penetration depth: to 12 in. (30 cm)
Furrow depth: to 10 in. (25 cm)
Furrow width: 9 to 24 in. (23 to 61 cm)
Check dam spacing: 9 to 96 ft (2.7 to 29.3 m)
Power requirements (drawbar):
55 hp (41 kW) light soils, medium depth
75 hp (56 kW) heavy soils, medium depth
120 hp (89 kW) heavy soils, full depth

Availability:

Laird Welding and Manufacturing Works
Box 1053
531 South Highway 59
Merced, CA 95340
(209) 722-4145

Drawings (RM25-01 to 14) and a Service and Parts Manual are available from:

USDA Forest Service
Equipment Development Center
444 East Bonita Ave
San Dimas, CA 91773
(714) 599-1267 or (213) 332-6231
FTS 793-8000

Land Imprinter

Specifications:

Pattern width: 6 ft, 7 in. (2 m)
Drum width: 3 ft, 3 in. (1 m)
Drum diameter (excluding imprint patterns): 3 ft, 3 in. (1 m)
Pattern depth to 6 in. (15 cm)
Power requirements (flywheel): 60 to 105 hp (45 to 78 kW)

Availability:

Laird Welding and Manufacturing Works
Box 1053
531 South Highway 59
Merced, CA 95340
(209) 722-4145

Rippers

Specifications:

Depth: to 7 ft (2.1 m)
Power requirements (flywheel): 172 hp (128 kW) minimum

Availability:

Agristruction, Inc.
41286 Road 124
Orosi, CA 93647
(209) 528-4788

American Tractor Equipment Co.
9131 San Leandro St
Oakland, CA 94603
(415) 638-2466

CRC-Kelley Products
Box 4700
Brownsville, TX 78520
(512) 546-5346

J. I. Case Co.
700 State St
Racine, WI 53404
(414) 636-6011

Caterpillar Tractor Co.
100 Northeast Adams
Peoria, IL 61629
(309) 675-1000

Clark Equipment Co.
Michigan Division
Box 547
Benton Harbor, MI 49022
(616) 927-7200

Fiat-Allis Construction Machine Inc.
106 Wilmont Rd.
Deerfield, IL 62710
(312) 948-5500

H&L Tooth Co.
1540 S. Greenwood Ave.
Montebello, CA 90640
(213) 721-5146

Chisel Plows

Specifications:

Width: 5 to 57 ft (1.5 to 17.4 m)
Depth: 4 to 12 in. (10 to 30 cm)
Shank spacing: 12 to 32 in. (30 to 81 cm)
Power requirements (drawbar): 30 to 315 hp (22 to 235 kW)

Availability:

Chisel plows are available from most farm implement manufacturers or farm equipment dealers.

Fertilizing and Mulching

Power Mulchers

Specifications:

Spread rates: to 15 tons/hr (13.6 metric tons/hr)
Spread distance: to 70 ft (21 m)
Adhesive pump capacity: to 50 gal/min (189 L/min)
Power ratings: 30 to 109 hp (22 to 81 kW)

Availability:

Finn Equipment Co.
2525 Duck Creek Rd.
Cincinnati, OH 45208
(513) 871-2529

Reinco, Inc.
Box 584
Plainfield, NJ 07061
(201) 755-0921

Hydraulic Seeder-Mulcher

(see page 125)

Seedbed Preparation

Disk Harrows

Specifications:

Width: 6 ft, 7 in. to 50 ft (2 to 15.2 m)
Depth: to 12 in. (30 cm)
Disk diameter: 18 to 26 in. (46 to 66 cm)

Weight: to 594 lb per ft (884 kg/m)
Power requirements (drawbar): 40 to 315 hp (30 to 235 kW)

Availability:

Disk harrows are available from most farm implement manufacturers and farm equipment dealers.

Klod Buster

Specifications:

Length: 40 ft (12 m) extensions to 160 ft (49 m)
Weight: 970 lb (440 kg)
Power requirements: Klodbuster easily attaches to most trucks or tractors

Availability:

Finn Equipment Co.
2525 Duck Creek Rd.
Cincinnati, OH 45208
(513) 871-2529

Springtooth Harrows and Field Cultivators

Specifications:

Width: 3 ft, 9 in. to 60 ft (1.1 to 18.3 m)
Depth: to 6 in. (15 cm)
Power requirements (drawbar): 20 to 315 hp (15 to 235 kW)

Availability:

Spring tooth harrows or field cultivators are available from most farm implement manufacturers and farm equipment dealers.

Spike Tooth Harrows

Specifications:

Width: 4 to 75 ft (1.2 to 22.9 m)
Power requirements (drawbar): 20 hp (15 kW) minimum

Availability:

Brillion Iron Works
200 Park Ave.
Brillion, WI 54110
(414) 756-2121

Deere and Co.
John Deere Rd.
Moline, IL 61265
(309) 752-8000

Degelman Industries, Ltd.
Box 963
Regina, Sask., Canada S4P 3B2
(306) 543-4447

Farm King, Ltd.
Box 1450
Morden, Man., Canada ROG 1J0
(204) 822-4467

Farnum Equipment Co.
Box 21447
Phoenix, AZ 85036
(602) 244-8261

Ferguson Manufacturing Co.
Box 1098
Suffolk, VA 23434
(804) 539-3409

Flexi-Coil, Ltd.
Box 1928
Saskatoon, Sask., Canada S7k 3R3

J. A. Freeman & Son, Inc.
2034 Northwest 27th Ave.
Portland, OR 97210
(503) 222-1971

International Harvester Co.
Agricultural Equipment Division
401 North Michigan Ave.
Chicago, IL 60611
(312) 836-2000

Kewanee Machinery Division
Chromalloy America Corp.
1516 Burlington Ave.
Kewanee, IL 61443
(309) 852-2191

Lear Siegler
Noble Division
515 North 16th
Sac City, IA 50583
(712) 662-4731

McFarlane Manufacturing Co., Inc.
1259 Water St.
Sauk City, WS 53583
(608) 643-3321

Melroe Division Agricultural Products
Clark Equipment Co.
Box 1215
Bismarck, ND 58501
(701) 222-5000

Northern Wisconsin Manufacturing Co.
Box 158
Pepin, WI 54759
(715) 442-4111

United Farm Tools, Inc.
Box 9175
South Charleston, WV 25309
(304) 768-8221

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